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Commercial Cod Farming Operations Newfoundland 1988

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ABSTRACT

The farming of Atlantic cod (*Gadus morhua*) was undertaken by Sea Forest Plantation Ltd. during the 1988-89 season at four locations in Newfoundland. Three locations were in the Northern Peninsula area (Griquet, St. Lunaire, and Crouse) and the fourth was located at Bay Bulls. Live fish were collected from cod traps, transferred to holding pens (June-September), fed capelin to satiation for one to five months, and harvested when market conditions and prices were favourable (October-January). Data was collected from all phases of the operation including collection, transport, feeding, and harvesting. Biological parameters examined consisted of growth (from tagging studies and farm records), mortalities, parasites, disease, stress, water temperatures, food conversion ratios (FCR), and condition factors (K-factors). General observations and recommendations dealing with farm husbandry and logistical problems are also presented.

RÉSUMÉ

Au cours de la saison 1988-1989, Sea Forest Plantation Ltd a entrepris l'aquiculture de la morue de l'Atlantique (*Gadus morhua*) dans quatre localités de Terre-Neuve. Trois de ces exploitations étaient situées dans la région de la péninsule Northern (Griquet, St. Lunaire et Crouse), alors que la dernière était à Bay Bulls. Le poisson, retiré vivant des pièges à morue et transféré dans des enclos (de juin à septembre), a été nourri à satiété de capelans pendant un à cinq mois, pour être récolté lorsque les conditions du marché et les prix étaient propices (entre octobre et janvier). Les données recueillies à toutes les étapes de l'opération comprennent la cueillette, le transport, l'alimentation et la récolte. Les paramètres biologiques étudiés concernent la croissance (au moyen d'opérations d'étiquetage et de relevés faits sur les fermes), les mortalités, les parasites, les maladies, le stress, la température de l'eau, les indices de transformation et les coefficients de condition (coefficients K). Le rapport contient également des observations générales et des recommandations touchant les fermes aquicoles et les problèmes logistiques qu'elles rencontrent.

PREFACE

Project monitoring, co-ordination and technical assistance was provided to Newfoundland cod farm operators by Eugene M. Lee on behalf of the Department of Fisheries and Oceans, St. John's, Newfoundland, under DFO/DSS Contract No. FP001-9-2037/01-XAQ.

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1. INTRODUCTION

Cod farming initiatives were first undertaken in Newfoundland in the late 1880's, and primarily addressed the early life stages of the cod fish. A hatchery situated in Dildo, concentrated on the rearing of cod larvae to be released into the ocean for the purpose of enhancing stock recruitment of the wild population. This project was shortly abandoned as there were no noticeable results in terms of fish population increases. The method of choice for the present operation is based upon the ongrowing of juvenile and adult cod, thus bypassing the larval stages.

Initial experimental work performed in 1986 by Sea Forest Plantation Ltd. of St. John's consisted of a four-pen farm situated at Bay Bulls. This yielded encouraging results and was followed up the next year (1987) with a twelve-pen farm at Bay Bulls and a pilot farm of two pens situated at Fogo. Promising results from these projects led to the establishment of four larger farms during the 1988 season at Bay Bulls (20 pens), and three locations on the Great Northern Peninsula namely, Griquet (30 pens), St. Lunaire (20 pens), and Crouse (8 pens). Due to the failure of the inshore fishery, farms at Griquet and St. Lunaire were only filled to half capacity.

The basic farming procedure consists of the purchase and collection of live fish from fishermen's cod traps during the trapping season, transferral of the fish to holding pens, feeding to enhance growth, and subsequent harvesting. The financial basis of the operation is that fish can be obtained at a low price early in the season (spring and summer) when the market is glutted, fed with a cheap food source (capelin), and sold at a higher price as quality fresh fish when markets are improved (late fall and early winter).

The operation was a benefit to fishermen in that prices they received for live fish were higher than those offered by traditional buyers. Furthermore, fishermen were provided with

a much needed outlet for their cod during times of glut when plants were only buying limited quantities. Fishermen fishing capelin traps could also take advantage of the farm's need for capelin as a food source.

This report provides a basic overview of farming procedures and their associated logistical and biological problems. Biological parameters such as growth rates, mortalities, feeding, parasites, disease, stress, temperatures, food conversion factors, and condition factors are presented and examined in detail. Part of the data was generated from fish tagging and independent sampling, while other information is derived from records obtained from the individual farms. Recommendations are put forward in a number of areas which hopefully can improve the operation if it is undertaken again.

2. FARM METHODOLOGY

2.1. Structure

A typical farm consisted of hinged wooden catwalk sections 5 ft (1.5 m) in width by 10 ft (3.0 m) in length with a 4-5 ft (1.2-1.5 m) high rail on both sides (lengthways) and styrofoam billets within to provide floatation. These are connected via a series of eyebolts to form 3.4 ft. (1.1 m) by 4 ft (1.2 m) sections which make up a standard pen. These parallel pens contain a net of 45 mm knotless nylon twine with dimensions of 40 ft (12.2 m) long by 37.5 ft (11.4 m) wide by 19 ft (6.0 m) deep; the actual depth in the water is 15 ft (4.6 m) because of attachment to the 4 ft (1.2 m) overhead rails. Weights are suspended from the net bottom corners and middle portions to maintain proper net shape. The net, hanging properly in the water column, provides 22,500 cubic feet (637 cubic meters) of space. A nylon zipper was sewn into the bottom center of each net approximately 4 ft (1.2 m) in length which could be opened and closed to facilitate the removal of mortalities and

unconsumed rations. Another net of the same basic dimensions, but designed with a 6 ft (1.8 m) long funnel of 3 ft (0.9 m) diameter hanging from the bottom center, was employed on the northern farm locations. The bottom of the funnel is secured with twine which can be untied to release any mortalities occurring within the pen.

2.2. Collection

The collection phase of the operation is centered around the trap-fishing season in each respective location (Bay Bulls June-August; Northern Peninsula July-September). Modified trap skiffs with fiberglassed holds and one specially-built aluminum boat were used as the collectors. All vessels were equipped with hydraulic winches, dip nets, water pumps, and oxygen aeration systems. When water and air temperatures necessitated, ice was used to lower the hold water temperature.

A crew of two men per boat performed the collection procedure. If necessary, this began with the addition of ice to the hold. The collector boat then steams to a point adjacent to the cod trap where the hold is pumped full of fresh sea water. Next, the collector boat attaches to the trap "v line" at the back of the trap in a position parallel with the fisherman's boat (with the catch between the two). The aeration system is turned on, a set of weight scales is attached to the dip net and the hydraulic winch is used to dip the live fish from the trap into the water-filled hold. When the hold is full (2000 to 3000 lbs for the skiffs, depending on weather conditions, and up to 4000 lbs for aluminum collector) or the trap is empty, a tarpaulin is tied over the hold to reduce the stress from sunlight and the collector boat makes the trip back to the farm. At the farm, the collector boat is tied up to the appropriate pen and the dipping procedure is reversed with the live fish deposited into the pen. The sea water is pumped out of the hold and, if fish are available at other cod traps, the procedure is repeated.

2.3. Sorting

After collection, fish were size sorted (large, small) into the pens. For all farms, the average large fish measured 57.8 cm and weighed 2.0 kg, while the average small fish measured 44.8 cm and weighed 1.2 kg. Sorting was performed to facilitate better feeding in that when large and small fish are held together the large fish tend to out-compete the small for feed. It can also be suggested that the procedure reduces the risk of cannibalism. However, with fish all of 30 cm or more in length, this tends to be negligible. Sorted fish is also desirable at harvest time when external factors may necessitate the harvesting/processing of only large or only small fish on any given day.

The fish sorting unit used was custom fabricated for farm operations. Inclined circular rods divide the internal space of the sorter into upper and lower compartments. The rods are set to a pre-determined spacing to allow smaller fish through while keeping the large fish on top. The sorter was placed upon a set of digital scales between two empty pens and adjacent to two pens which contain unsorted fish. A portion of the unsorted fish in one pen was "drawn up" (hand raising of the net twine) into the nearest corner and from here the fish were "dipped up" using a hydraulic winch (dip net system hanging from an overhead boom). Fish were dipped up and laid gently down into the sorter, whereupon the small fish pass through rods to the bottom and slide down to a clamped swinging door, while the large fish slide down along the top of the rods lodging against another clamped swinging door on the opposite side of the sorter. The total weight was recorded, the door retaining the large fish was released, and the fish slid into the large pen. The weight of the small fish was recorded and they were released into the opposite pen. The weight of the large fish was calculated by subtracting the weight of the small fish from the total weight. When the unsorted pens were empty, the equipment was moved to the next station between four pens and the next two unsorted pens

were sorted. This process continued until all the farm pens were sorted.

2.4 Feeding

The diet of the fish consisted mainly of capelin which was provided to a level of approximately 6-10% of stock weight every second day. Frozen capelin were thawed overnight in large metal containers (through which there was a constant flow of fresh or salt water) situated dockside at all locations. Transportation from the containers to the collector boat holds was facilitated by a large hose and water pressure which served to push the capelin through. Appropriate amounts of this feed, as dictated by various pen stocks (weight), were then distributed using the hydraulic winch and boom with weight scales attached.

A small amount of moist pellet feed was provided to the fish at Bay Bulls on two occasions. The first was as a medium to carry an antibiotic treatment (TM - 50) to counteract a disease outbreak which occurred in late August - early September. This medicated feed ((Fish meal 56%, Minced capelin 39%, and TM-50 5%) was supplied at an amount of approximately 2% of fish weight every second day for the period September 8-17. The feed mixture was produced on site using a mechanical mixer/extruder to form the pellets. The feed was held in plastic tote pans, transported to the farm by collector boat, and distributed to the fish. A second use of moist pellet feed (Fish meal 58%, Minced capelin 40%, and Vitamin premix 1.5%) at Bay Bulls was applied in an experiment to determine any differences in fish condition and growth between large and small fish and large and small capelin-fed fish. This was conducted during the period October 31 - November 30 with pens 14 (large) and 17 (small) receiving capelin and pens 16 (large) and 18 (small) being fed pellets.

A small amount of dry pellet salmon feed was introduced experimentally as well, but the fish showed little interest. It

should also be noted that the live capelin held in pen # 12 at Bay Bulls would feed upon their own eggs. This may provide an opportunity to reduce feed costs as capelin could be held alive thus avoiding such factors as freezing costs. The capelin eggs were obtained from the bottom of the collector boat holds after feeding with capelin.

2.5. Harvest

Fish were harvested from all locations using basically the same standard procedure consisting of: (1) removal of fish from the farm using collector boats and the hydraulic winch - dip net system; (2) holding of the fish in containers of salt water diffused with carbon dioxide gas which served to mildly anesthetize the fish (approximately 3-5 minutes); (3) cutting the throats in front of the heart, or severing of several gill arches; (4) transferral of the fish to containers where they are allowed to bleed into water (fresh or salt) for 10-15 minutes; (5) dipping the bled fish into stackable tote pans for weighing; (6) manual gutting; (7) HOG (head on gutted) fish were cleaned in troughs with a continuous flow of fresh or salt water; (8) fish were packed head to tail and iced in tote pans which were stacked to await processing; (9) fish were processed using standard procedures employing both hand cutters and filleting machines; (10) product is packed for market (both fresh and frozen).

At both St. Lunaire and Crouse, fish were exposed to carbon dioxide gas and gill arches and throats were cut on the farm itself. Fish were then transferred to the salt water-filled collector boat hold in which they were allowed to bleed during the trip from the farm to dockside. In Griquet and Bay Bulls, live fish were transferred by collector boats directly to dockside, winched into grey containers and exposed to carbon dioxide gas, following which they were cut and allowed to bleed in containers (fresh water at Bay Bulls, salt water at Griquet). HOG fish from the northern locations (Griquet, St. Lunaire and

Crouse) were iced down, placed head to tail in tote pans, packed on board refrigerated tractor trailers and trucked to Witless Bay (12 hr trip) for final processing (with the exception of some fish processed at St. Anthony before the closure of the Fishery Products International plant). Most of the final product was trucked fresh immediately to markets in the United States. However, a sizeable portion of the small fillets was packed as frozen block and shipped to available markets.

3. RESULTS

3.1. Temperature

With respect to temperature, all locations exhibited a relatively similar pattern with a fairly steady rise from 4-7°C in June to a peak of 12-15°C in mid to late August, followed by a steady decline to temperatures ranging from 2°C to 7°C in late October - early November. The highest temperature recorded was 15°C at Bay Bulls on August 30-31 (Figure 1, page 8). The lowest temperature recorded was -1.4°C on January 27 also at Bay Bulls. St. Lunaire and Crouse both had little temperature difference over depth, indicating good mixing throughout the water column (Figures 2 and 3, pages 9 and 10). Griquet revealed marked and consistent differences in temperature with respect to depth (Figure 4, Page 11). Surface temperatures averaged approximately 1.5-2°C higher than those at 30 feet and approximately 6-8°C higher than temperatures at 60 feet. The Griquet temperature regime does, however, draw much closer together in mid-September with little more than a 1°C difference between all depths. Crouse displayed a number of sharp peaks and troughs in its temperature regime, indicating as much as 3°C rise or drop in temperature at all depths over a period of 24 hours.

The temperature anomalies of Griquet can be attributed partly to the general rule of decreasing temperature with increasing depth, but may be due to the presence of a shallow bar approximately 15 feet (4.6 m) in depth, which extends across the

BAY BULLS TEMPERATURE PROFILE

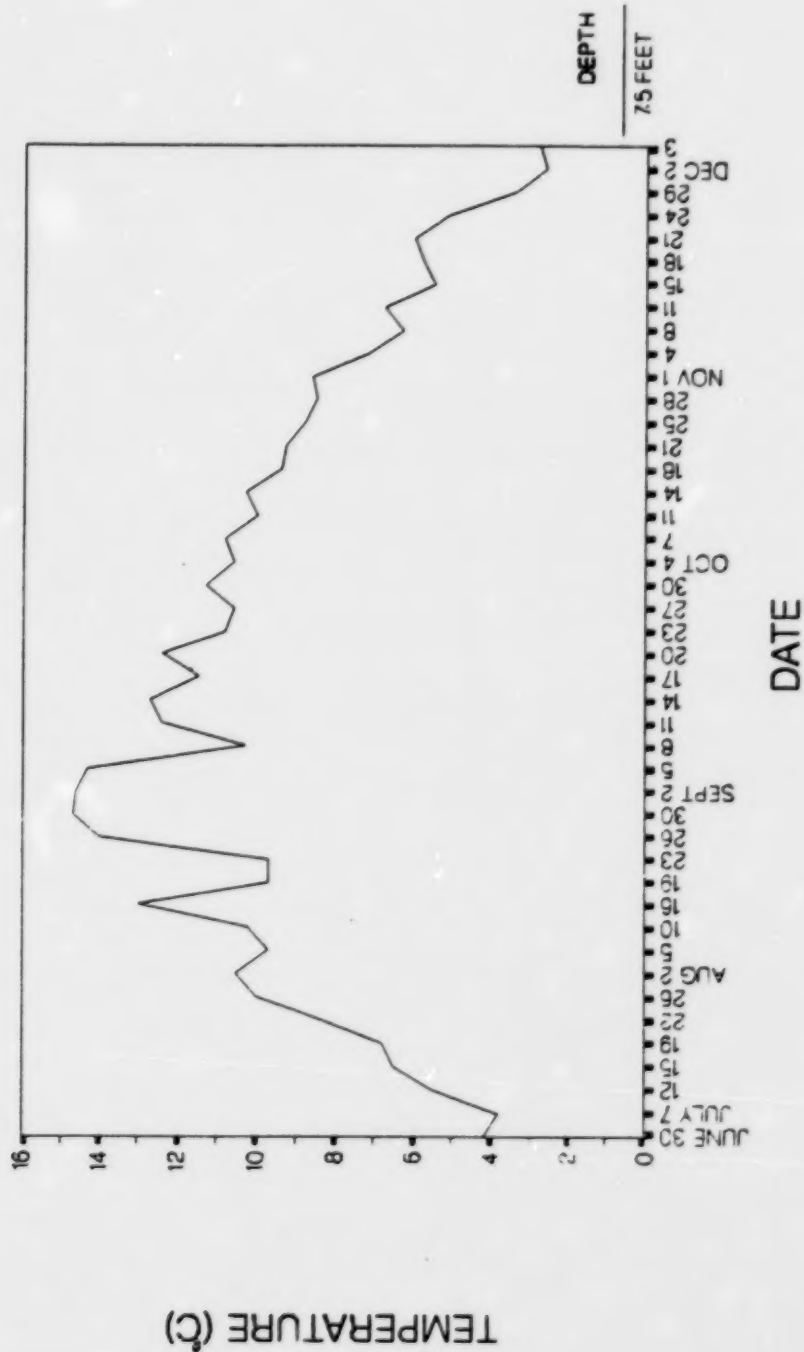


FIGURE 1

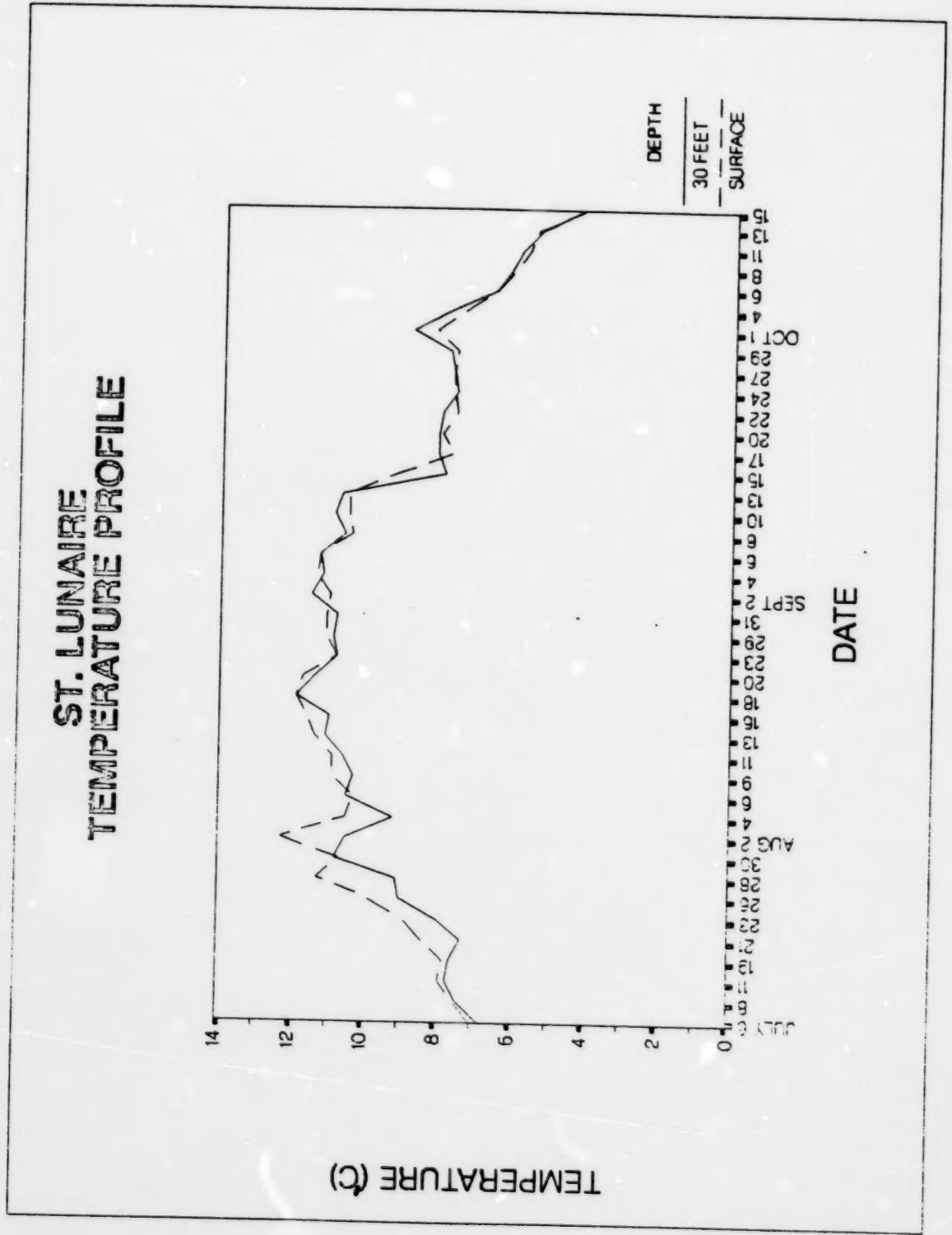


FIGURE 2

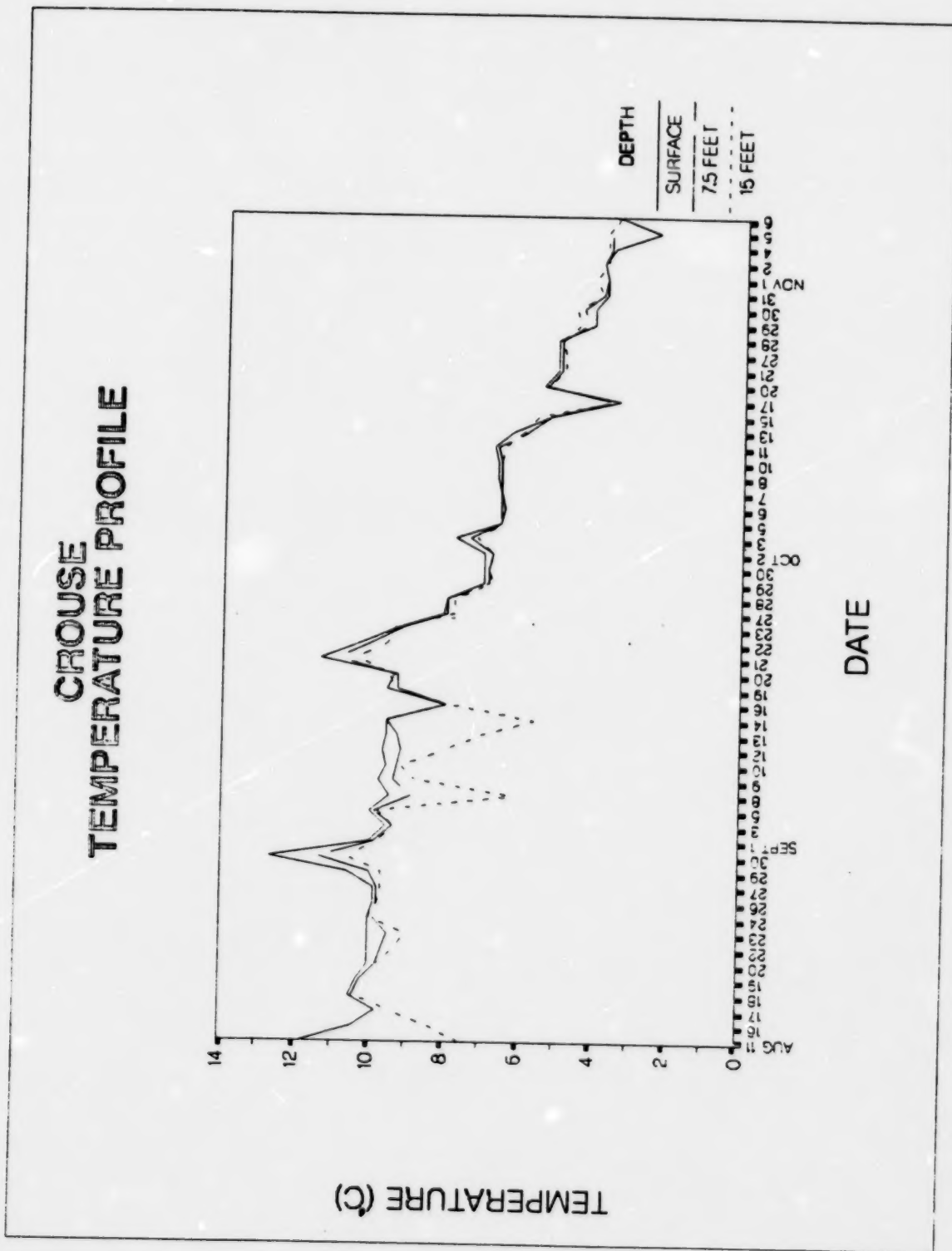


FIGURE 3

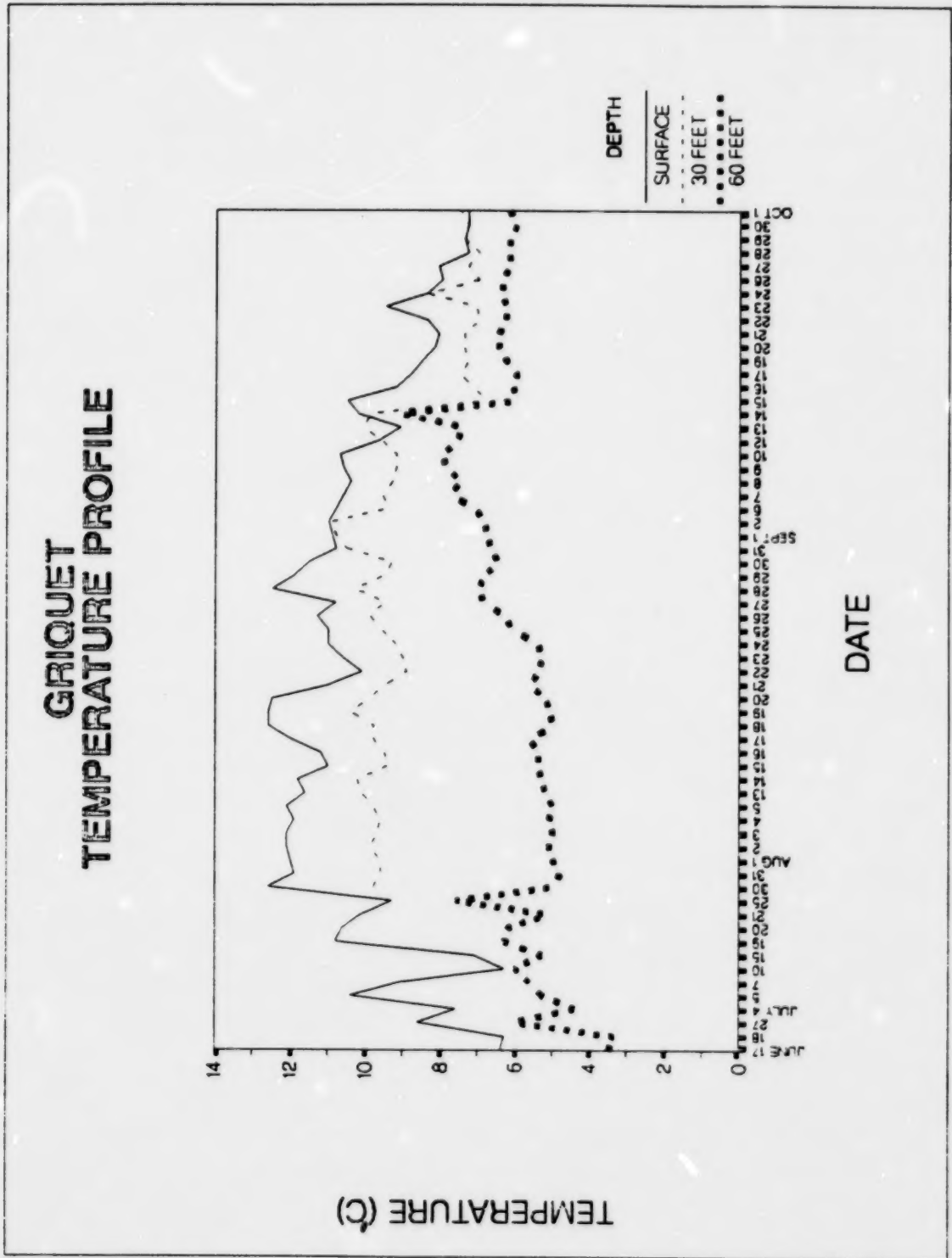


FIGURE 4

mouth of Griquet Harbour. This barrier may have allowed only the upper layers (15-20 ft, 4.6-6.1 m) of the outside water column to flow into the harbour, thus creating the stratified layers that were evident. Strong westerly winds appeared to push large volumes of deeper outside water over the bar and into the harbour as was evident in early October when the temperature range at depth was drawn much closer together. This theory of bar interference was supported by a noticeable thermocline encountered at 35-40 feet (10.7-12.2 m) by SCUBA divers, and by uniform temperatures throughout the water column just outside the bar.

All locations exhibited substantial fluctuation in day-to-day and weekly temperatures, indicating good water exchange. This exchange appeared to be fairly consistent in all locations except Crouse, which revealed a number of noticeable sharp peaks and drops in temperature over the season. This is most likely a direct result of farm location, situated at the bottom of 2-3 mile (3.2-4.8 km) long Cape Rouge Harbour. It would require strong winds for extended periods to produce large volume inward water movement and subsequent sharp temperature change. From farm records, this appears to be the case as each temperature peak or trough is preceded by a period of strong winds.

It was unfortunate that Bay Bulls' temperatures were taken only at a depth of 15 feet (4.6 m) (Figure 1, Page 8). Periodic temperatures taken at different depths indicated definite stratification between surface and bottom layers with the upper layer as much as 4-5°C higher. This stratification however, lessened and eventually disappeared by late August to mid-September, giving way to a homogeneous temperature regime due to offshore storm mixing. During the last week in January a uniform temperature of -1.4°C was reported throughout the entire water column.

3.2. Tagging

Fish were tagged and released into various pens at all locations to determine growth rates, organ weights, and K-factors (condition factor = $(\text{weight}/(\text{length}))^3 \times \text{conversion}$). The tags used were grey Floy "T-tags" with individually numbered plastic tubes. Tags were inserted between the dorsal fin rays using a Floy Dennison tagging gun. Lengths were taken on an 80 centimeter measuring board, fish weights were obtained using a hand held scales, and organ weights were acquired with a table-top Gold Brand KCOL-PA 2 kilogram scales. Return rates of tagged fish varied for all locations. Of 288 fish tagged at Griquet, 145 (50%) were recovered; of 150 fish tagged at St. Lunaire 61 (40%) were recovered; of 192 fish tagged at Crouse 61 (32%) were recovered; of 329 fish tagged at Bay Bulls 23 (7%) were recovered; of 204 fish tagged at Bay Bulls for a pellet versus capelin feeding experiment 88 (43%) were recovered. The large discrepancies between returns and number of fish tagged can only be speculated upon, but are due most likely to a combination of factors. These include mortalities not recovered; tags dropping out; fish escapement through net tears, and failure to identify tagged fish at harvest time which proved to be difficult due to the fact that tags were grey (fish coloured) and in many instances were coated with algae. The extremely low figure of 7% return rate at Bay Bulls was probably a direct result of the disease outbreak which occurred late August to mid-September. Infected fish exhibited swelling of the fin areas (the dorsal fin in particular) which could easily lead to tags dropping off, infection mortalities were high (up to 2400 lbs. per day), and many tagged fish were lost. Infected fish also tended to rub against the net mesh quite vigorously, presumably to reduce irritation, which could lead many tags to be "hooked" out over the disease period.

In terms of mean % weight gain (Table 1, Page 14) the results were: Griquet 66.5%; St. Lunaire 46.7%; Crouse 39.7%, and Bay Bulls 18.1%. The mean % length gain results were: Griquet

TABLE 1
TAGGED FISH DATA
FARM MEANS

	Griquet	St. Lunaire	Crouse	Bay Bulls
Initial Length (cm)	49.9	50.0	52.0	53.9
Final Length (cm)	55.6	53.6	56.1	59.7
% Length Gain	12.3	7.6	8.2	11.1
Initial Weight (kg)	1.3	1.3	1.4	2.4
Final Weight (kg)	1.9	1.8	1.9	2.8
% Weight Gain	66.5	46.7	39.7	19.1
Liver Weight (kg)	0.16	0.12	0.14	0.10
% Liver Weight	8.1	6.2	6.5	3.3
Gonad Weight Female (kg)	0.11	0.05	0.12	0.08
% Gonad Weight Female	5.5	2.6	5.3	3.1
Gonad Weight Male (kg)	0.07	0.04	0.06	0.12
% Gonad Weight Male	2.8	1.7	4.0	3.6
Initial K factor	.93	.93	.93	1.62
Final K factor	1.07	1.06	1.02	1.34
Head on Gutted Weight (kg)	1.7	1.5	1.5	1.7

TABLE 2

Duncan's Multiple Range Tests for Significant
(P = 0.05) Differences Between Farm Locations
for Various Biological Parameters Using
Tagged Fish Data

Note: * denotes two groups which are significantly different
at the 0.05 level
GR = Griquet; ST = St. Lunaire; CR = Crouse;
BB = Bay Bulls; S.D. = Standard Deviation

Parameter	Test Results						
Initial Length (cm)	Mean	S.D.	GR	ST	CR	BB	
	49.9	10.3	GR				
	50.0	9.4	ST				
	52.0	7.9	CR	no two groups			
	53.9	8.2	BB	significantly different			
Final Length (cm)	Mean	S.D.	ST	GR	CR	BB	
	53.6	9.4	ST				
	55.6	9.6	GR				
	56.1	7.6	CR				
	59.7	8.2	BB	*			
% Length Gain	Mean	S.D.	ST	CR	BB	GR	
	7.58	4.89	ST				
	8.17	5.17	CR				
	11.12	5.69	BB	*	*		
	12.29	6.73	GR	*	*		
Initial Weight (kg)	Mean	S.D.	GR	ST	CR	BB	
	1.3	0.83	GR				
	1.3	0.81	ST				
	1.4	0.67	CR				
	2.4	1.16	BB	*	*	*	
Final Weight (kg)	Mean	S.D.	ST	CR	GR	BB	
	1.8	0.97	ST				
	1.9	0.96	CR				
	2.0	1.03	GR				
	2.8	1.20	BB	*	*	*	
% Weight Gain	Mean	S.D.	BB	CR	ST	GR	
	19.09	15.29	BB				
	39.73	23.68	CR	*			
	46.71	31.05	ST	*			
	66.50	32.05	GR	*	*	*	

Duncan's Table Continued

Parameter	Test Results						
Initial K factor	Mean	S.D.		ST	GR	CR	BB
	9.26	1.78	ST				
	9.28	1.57	GR				
	9.35	2.02	CR				
	16.16	9.14	BB	*	*	*	
Final K factor	Mean	S.D.		CR	ST	GR	BB
	10.15	1.61	CR				
	10.65	1.47	ST				
	10.70	1.21	GR				
	13.39	6.06	BB	*	*	*	
Head on Gutted Weight (kg)	Mean	S.D.		ST	CR	GR	BB
	1.50	0.80	ST				
	1.54	0.76	CR				
	1.66	0.87	GR	no two groups			
	1.67	0.76	BB	significantly different			
Liver Weight (kg)	Mean	S.D.		BB	ST	CR	GR
	0.10	0.10	BB				
	0.12	0.10	ST				
	0.14	0.11	CR				
	0.16	0.10	GR	*	*	*	
% Liver Weight	Mean	S.D.		BB	ST	CR	GR
	3.31	2.48	BB				
	6.18	3.09	ST	*			
	6.48	2.64	CR	*			
	8.10	2.68	GR	*	*	*	
Gonad Weight (kg)	Mean	S.D.		ST	CR	GR	BB
	0.04	0.05	ST				
	0.08	0.10	CR	*			
	0.09	0.09	GR	*			
	0.10	0.11	BB	*			
% Gonad Weight	Mean	S.D.		ST	BB	GR	CR
	2.05	1.73	ST				
	3.37	3.36	BB				
	3.88	3.36	GR	*			
	3.95	3.67	Cr	*			

12.3%; St. Lunaire 7.6%; Crouse 8.2%; and Bay Bulls 11.1%. The mean % liver weight results were: Griquet 8.1%; St. Lunaire 6.2%; Crouse 6.5%; and Bay Bulls 3.3%. The mean % gonad weight (male) results were: Griquet 5.5%; St. Lunaire 2.6%; Crouse 5.3%; and Bay Bulls 3.1%. The mean % gonad weight (female) results were: Griquet 2.8%; St. Lunaire 1.7%; Crouse 4.0%; and Bay Bulls 3.6%. Initial mean K-factors were: Griquet 9.3%; St. Lunaire 9.3%; Crouse 9.3%; and Bay Bulls 16.2%. Final K-factors were: Griquet 10.7%; St. Lunaire 10.6%; Crouse 10.2%; and Bay Bulls 13.4. All variables were compared between all farm sites in terms of statistically significant differences in Table 2, Pages 15 and 16.

3.3. Parasites

The typical external parasites (*Lernaeocera branchialis*, *Clavella adunca*, *Caligus* sp.) of cod were evident at all farm locations. These all fall within the taxonomic grouping of Class: Crustacea, Sub-class: Copepoda, Order: Caligidea. *Lernaeocera branchialis* (commonly referred to as *Lernaea*) is dark red in color, macaroni shaped, and about 1-4 cm in size. It is found in the buccal cavity of cod where it is attached to the gill arches, tongue, or directly to the heart of the fish. *Lernaea* is deleterious to the health of the fish in terms of weight gain and K-factor. This effect is much more evident in small fish (20-40 cm) than in larger individuals (41 + cm). One fish may harbour up to 6 to 8 *lernaea* and ultimately succumb to the infection, although the usual infection rate is 1 or 2 per fish and is rarely fatal. *Lernaea* infection rates were found to be: 4.5% Griquet; 4.2% St. Lunaire; 8.7% Crouse; and 8.5% Bay Bulls. While none of these infection rates can be considered high, the effects of *Lernaea* should not be overlooked with respect to cod farming. It appears that the effects of *Lernaea* are most evident in the mortality of the initial post-capture period. At Bay Bulls 37% of collection mortalities harboured *Lernaea* infections compared with only 8.5% of the tagged fish. This indicates the presence of *Lernaea* reduces the fish's ability

to cope with post-capture stress. It should also be noted that the intermediate stage of *Lernaea* is present in a number of species found in and around the farm site. These include flounder, sculpins and most importantly lumpfish which are the primary vector for this stage. Twenty-five lumpfish were removed by diving from within the farm pens of Bay Bulls this past season, and upon examination all of these fish were found to contain the *lernaea* intermediate stage (200-300 per fish). Greater care in eliminating "trash" fish during the transfer from collector boat to the farm could solve a large part of the problem.

Clavella adunca is a small (2-4 mm) white parasitic copepod found usually around the anus, upon fin edges, or in the buccal cavity (upon the gill arches and gill filaments). Its characteristic bilateral shape of two white protrusions is due to extending egg cases, the contents of which are released into the water column to start the cycle again when the parasite dies or drops off. *Clavella* sp. results in little noticeable or measurable differences in terms of fish health. Large numbers found upon gill arches and filaments cause excess mucous to be exudated thereby interfering with the oxygen transfer. Those which attach to gill filaments also tend to constrict blood vessels which in turn reduces blood flow ultimately reducing the fish's capability for oxygen uptake. *Clavella* sp. were found in fish from all locations; however, numbers were never out of the typical range for wild fish and thus should not be cause for concern.

Caligus sp. (often referred to as "fish lice") is a parasitic copepod found upon the skin of cod and other marine fish species. It is brown in colour, about one cm in length and can be observed "scudding" along the fish's skin in small jerky movements. They can attach using suckers and cause skin irritation by means of a ventrally located rasping apparatus which allows them to penetrate and draw out blood and body fluids. While usually not a major concern in terms of fish

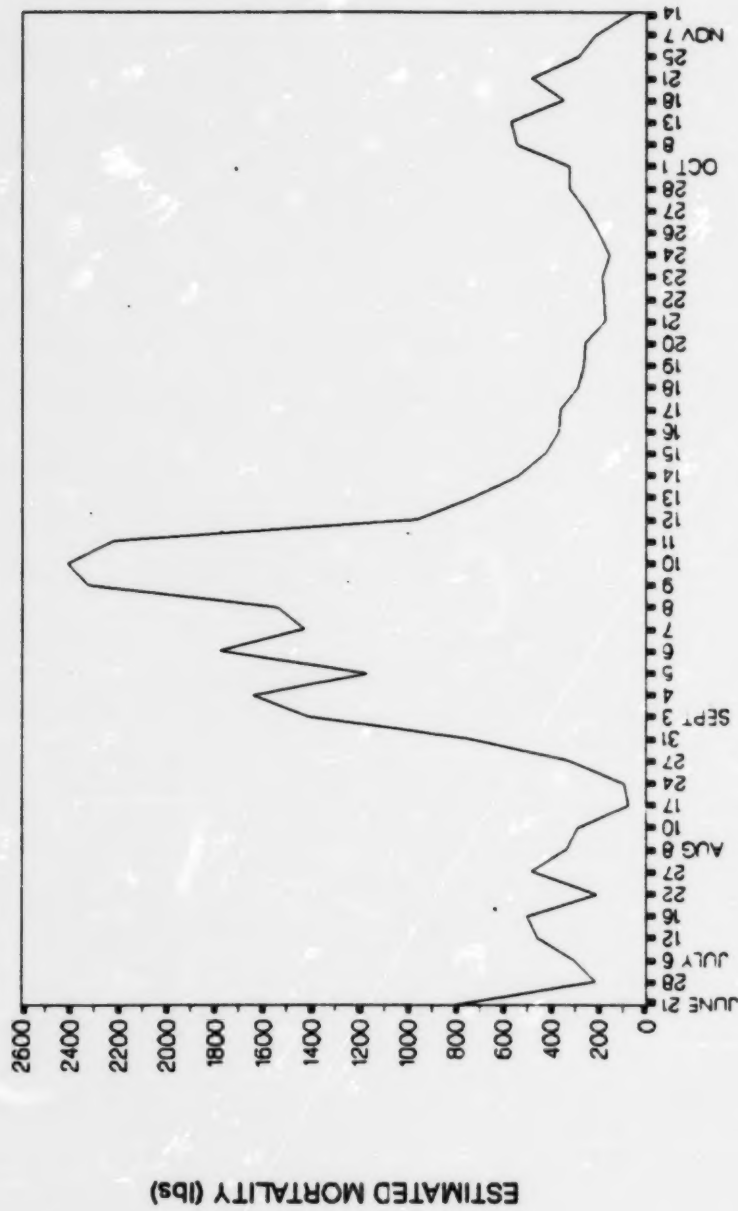
health, they can leave fish vulnerable to bacterial and viral pathogens which may be present in the water column. Most farm locations had infestation levels of 10-15% while Griquet had an 80-90% infection rate with as many as 5-6 parasites per fish.

Fillets from all locations were examined during processing for the presence of codworm (*Phocanema decipiens*) and found to have levels comparable to those of wild fish. Due to logistical and time constraints fish were not examined in terms of internal parasites. Although no direct damage was evident for a number of these parasites it should be kept in mind that intense cultivation of a species can lead to parasitic outbreaks unheard of previously due to changes in the host parasite balance.

3.4. Disease

All farms exhibited a number of minor disease occurrences. Exophthalmia ("pop-eye" or swelling of the eyes) observed in a number of individual fish is most likely due to pressure effects during collection and/or dietary deficiencies. Skeletal malformation (twisting of the spine) was evident in a number of collected fish, this being due to vitamin deficiencies in the wild. None of the capelin-fed farm fish had this problem. Bending of the spine, coupled with head and jaw deformities, was also noticed on a number of collected fish. This is due to a sporozoan parasite *Myxosomas cerebralis* which causes Whirling disease by penetrating the cartilage of the head region and destroying the organs of balance, which is followed by progressive ossification of the skeleton (Conroy and Herman, 1970). Bacterial fin rot and skin lesions were found at all sites primarily in individuals which were particularly stressed or sustained damage during collection. This usually resulted from "meshing" (entanglement in trap mesh), abrasions from contact with other fish or scrapes and cuts from improper handling. In most cases these fish progressively degenerated to the point they succumb and sink to the bottom or swim aimlessly about on the surface and are subsequently removed.

BAY BULLS ESTIMATED MORTALITIES



DATE

NOTE The data has been transformed to give the daily
mortalities over the staggered time intervals

FIGURE 5

A serious disease outbreak occurred at Bay Bulls, with mortalities increasing from an average of 50-100 pounds per day in early August to 2400 pounds per day in the first week of September (Figure 5, Page 20). Disease symptoms encountered were similar to those found in a Vibriosis (*Vibrio anguillarum*, bacteria) infection which is the most common form of bacterial septicaemia in marine fish farms (Roberts and Shepherd, 1986). Symptoms consisted of dark coloration, lumps or swellings located all over the exterior with particularly large gelatinous-like swellings in the dorsal and caudal fin areas, large lesions located ventrally which released a red exudate, bleeding in the eyes coupled with exophthalmia, loss of appetite, and loss of energy. Fish with terminal infections were observed by SCUBA divers to lie on the bottom meshes of the pens for two to three days before death. Mortalities and moribund fish were removed twice a day (during the peak period) through the pen bottom zippers with mortality weights estimated. Dead fish were released to the bottom which, in treating a bacterial infection, is a poor practice due to the fact that the dead and rotting fish release even more infective bacteria into the water column. Samples of whole fish, fish tissues, eye fluids, and gelatinous lump exudates were examined by the Department of Pathology and Microbiology of the Atlantic Veterinary College UPEI; however results were inclusive. The only positive identification was from eye fluid samples which were found to contain large numbers of gram negative bacilli identified as *Aeromonas sobria* which is associated with freshwater and sewage. No actual causative agent for the disease outbreak was identified. Water quality testing was carried out at different depths for dissolved oxygen, coliforms, chlorine, H_2S , and NH_3 . All test results were normal, leaving only the water temperature which was as high as $16^{\circ}C$ at the time as the only abnormality.

An antibiotic treatment was performed using the general antibiotic Oxytetracycline (the treatment of choice for acute septicaemias, such as vibriosis according to Roberts and Shepherd, 1986). The Tetracycline powder was combined with a moist feed

pellet (5% TM-50) and fed to all fish at a rate of approximately 2% of body weight every second day for a period extending from September 8 - 17. Following the antibiotic treatment, there was a marked decrease in mortality of approximately 200 pounds per day after a two week period (Figure 5, Page 20). This initial success however, was followed shortly (8-10 days) by another mortality increase up to 600 pounds per day in mid-October. These were most likely fish which harboured "chronic" infections at the treatment time, indicating either they didn't receive enough antibiotic feed due to their inability from infection to feed properly, or their infection was too far advanced for the antibiotic to be effective as a cure but merely served to delay their deaths.

The causative agent which resulted in the outbreak was never actually identified. *Aeromonas sobria* was probably a secondary infection resulting from, effluent from the adjacent fish plant, refuse dumped from boats in the harbour, community sewage, freshwater runoff, and bacteria released from decomposing fish directly under the farm site. The symptoms observed were suspiciously similar to a vibriosis outbreak; however this is only speculative and not supported by hard clinical evidence. It is probably a combination of high water temperatures, vitamin deficiencies from a monodiet of capelin, stress, and an opportunistic bacterial and viral fauna related to the above-mentioned site specific problems. Special care should be taken in future to continually test water quality, observe fish closely when water temperatures rise above 11°C, remove mortalities from the farm site, avoid excess feeding which contributes to the organic buildup of detritus, and perhaps employ a preventative antibiotic treatment in advance of high seasonal temperature peaks.

3.5. Mortality/Losses

Farm mortalities from all locations were divided into a number of categories dealing with progressive steps in the

TABLE 3
ESTIMATED FARM MORTALITY/LOSSES

	St. Lunaire	Griquet	Crouse	Bay Bulls	Combined
Total Fish Purchased	164880	350682	142798	478695	1137055
Transport Mortality	16650	35489	26693	73369	152201
% Transport Mortality	10.1	10.1	18.7	15.3	13.4
Delayed Transport Mortality	12000	20500	18500	21744	72744
% Delayed Transport Mortality	7.3	5.8	13.0	4.5	6.4
Total Transport Mortality	28650	55989	45193	95113	224945
% Total Transport Mortality	17.4	16.0	31.6	19.9	19.8
Post Transport Farm Total	136230	294693	97605	383582	912100
Sort Weight	147964	279987	98729	341911	868591
Sort Weight - Post Transport Wt.	11734	-14706	1124	-41671	-43519
Disease Mortality	0	0	0	41618	41618
% Disease Mortality	0	0	0	12.2	4.8
Escapement (Estimated)	9600	31100	0	0	40700
% Escapement	6.5	11.1	0	0	4.7
Post Sort Mortality/Loss	9600	31100	0	41618	82318
% Post Sort Mortality/Loss	6.5	11.1	0	12.2	9.5
Total Mortality/Loss	38250	87089	45193	136731	228883
% Total Mortality/Loss	23.2	24.8	31.7	28.6	20.1

husbandry process (Table 3, Page 23). The only category with true weights is transport mortality (fish were weighed for sale to the local fish plant). All other figures are estimates provided by SCUBA divers and farm management. Transport mortality refers to those fish which died during transport or shortly after being introduced to the farm. Transport mortalities for the different locations were: Griquet 35489 lbs (10.1%); St. Lunaire 16650 lbs (10.1%); Crouse 26693 lbs (18.7%), and Bay Bulls 73369 lbs (15.3%), which gives an overall average of 13.4%. Delayed transport mortality refers to those fish which died a number of days or in some cases weeks after initial collection. These were usually removed through the pen bottoms by SCUBA divers. Delayed transport mortalities for the different locations were: Griquet 20500 lbs (5.8%); St. Lunaire 12000 lbs (7.3%); Crouse 18500 lbs (13.0%); and Bay Bulls 21744 lbs (4.5%), which provides an overall figure of 6.4%. Disease mortality is only applicable to Bay Bulls where a serious outbreak occurred. Mortality was estimated by SCUBA divers at 41618 lbs (12.2%). Escapement loss refers to fish lost through rips and/or tears in the pen net meshes. Griquet lost an estimated 10300 lbs (3.7%), St. Lunaire lost approximately 9600 lbs (6.5%) while Crouse and Bay Bulls reported no escapement. Vandalism losses refers to fish lost due to an incident at Griquet where pens drawn up to the wharf for harvesting were cut loose during the night. The estimated loss was 20800 lbs (7.4%). Total mortality/losses is the combination of all aforementioned figures to provide the overall totals of Griquet 87087 lbs (24.8%), St. Lunaire 38250 lbs (23.2%), Crouse 45193 lbs (31.7%), and Bay Bulls 136731 lbs (28.6%), for a total combined figure of 228883 lbs (20.1%).

3.6. Food and Growth

To preface this section, it should be noted that this is a commercial operation and methods used to obtain data are performed by individuals using different equipment and are therefore questionable at the best of times in terms of accuracy and variability. The food and growth figures presented should not be considered definitive or accurate. They are, however,

TABLE 4

GRIQUET FOOD AND GROWTH SUMMARY

Pen #	Fish Size	Start Weight lbs	Start Density lbs/cuft	Projected Weight lbs	Production Weight lbs	Production Density lbs/cuft	Density Increase lbs/cuft	Projected Growth lbs	Actual Growth lbs	Difference Proj - Act lbs	% Growth	Feed Days	Total Feed lbs	Capellin	% Daily Growth	Food Conversion Ratio (FCR)
5	L	24033	1.07	32747	29566	1.31	0.24	8714	5553	-3161	23.1	35	34473		0.66	6.2
9	L	6464	0.29	9159	6950	0.31	0.02	2695	466	-2209	7.5	32	10075		0.23	22.3
11	L	16013	0.71	25776	23786	0.92	1.30	9765	4773	-4992	29.8	56	31240		0.53	6.5
15	L	12596	0.56	17744	18367	0.82	0.26	5148	5771	+623	45.8	37	20260		1.24	3.5
17	L	21746	0.97	30569	24180	1.07	0.10	8823	2434	-6389	11.2	37	34380		0.30	14.1
19	L	20107	0.89	30523	20270	0.90	0.01	10416	163	-10253	0.8	44	39630		0.02	243.0
21	L	16607	0.74	24225	16957	0.75	0.01	7618	350	-7268	0.02	41	29445		0.00	94.1
25	L	8779	0.39	13214	12785	0.57	0.18	4435	4006	-429	45.6	44	17235		1.04	4.3
6	S	20208	0.90	30241	26988	1.29	0.39	8780	8780	-1253	43.4	44	34583		0.99	3.9
10	S	7237	0.32	10190	9914	0.44	0.12	2677	2677	-276	37.0	33	10110		1.12	3.8
16	S	16942	0.75	24512	17000	0.76	0.01	158	158	-7512	0.9	36	25955		0.03	164.3
18	S	15522	0.69	22809	21146	0.94	0.25	5624	5624	-1663	36.2	35	22803		1.03	4.1
20	S	13405	0.60	21553	20538	0.91	0.31	7133	7133	-1015	53.2	45	27162		1.24	3.8
22	S	13587	0.60	22553	19086	0.85	0.25	5499	5499	-3467	40.5	44	29598		0.92	5.4
24	S	13439	0.60	22310	10655	0.47	-0.13	-2784	-2784	-11655	-20.7	47	29290		-0.44	-10.5
26	S	6400	0.28	11180	9642	0.43	0.15	3242	3242	-1538	50.6	44	15825		1.15	4.9
TOTAL		232985		349307	286650			87943	53865	-62457						412864
AVERAGES		14662	0.65	21832	17928	0.80	0.22	5496	3367	-3904	25.3	41	25804		0.63	35.2

Moet: Pen #23 was omitted because of a hole which permitted substantial escapement.
 Pen #7 and Pen #8 were omitted due to the fact they were vandalized with substantial fish loss.

TABLE 5

ST. LUNAIRE FOOD AND GROWTH SUMMARY

Run #	Fish Size	Sort Weight lbs	Sort Density lbs/cuft	Projected Weight lbs	Production Weight lbs	Production Density lbs/cuft	Density Increase lbs/cuft	Projected Growth lbs	Actual Growth lbs	Difference Proj - Act lbs	% Growth	Feed Days	Total Feed lbs Capelin	% Daily Growth	Feed Conversion Ratio (FCR)
3	L	17338	0.77	24786	22364	0.99	0.22	7448	5026	-2422	29.0	28	27687	1.04	5.51
5	L	13500	0.60	18992	17444	0.78	0.18	5422	3944	-1548	29.2	27	20702	1.08	5.25
7	L	7241	0.32	10155	10280	0.46	0.14	2914	3039	+125	42.0	27	11003	1.55	3.62
20	S	20086	0.89	27029	25234	1.26	0.37	6943	5148	-1795	25.6	24	25225	1.07	4.90
2	S	20073	0.89	27049	26720	1.19	0.30	6976	6647	-7750	33.1	24	25475	1.38	3.83
4	S	26456	1.17	38909	33535	1.49	0.32	12453	7079	-5374	26.8	29	41056	0.92	5.80
6	S	14513	0.64	21714	19266	0.86	0.22	7201	4753	-2448	32.7	30	24371	1.09	5.13
8	S	6049	0.27	8578	8531	0.38	0.11	2529	2482	-47	41.0	29	8441	1.41	3.40
TOTALS		12527		177142	163374			51886	38110	-2657			183960		
AVERAGES		15657	0.69	22143	20422	0.93	0.23	6485	4763	-332	32.4	27.3	22995	1.20	4.68

Note: Due to fish escapement, data from pen #1 has been omitted.

TABLE 6

CROUSE

FOOD AND GROWTH SUMMARY

(Data Not Available On Pen By Pen Basis)

Sort Weight (lbs)	98729
Sort Density (lbs/cuft)	0.55
Production Weight (lbs)	122347
Production Density (lbs/cuft)	0.68
Density Increase	0.13
Growth (lbs)	23623
% Growth	24.0
Feed Days	47
Total Feed (lbs Capelin)	140355
\$ Daily Growth	0.51
Food Conversion Ratio (FCR)	5.94

CROUSE PRODUCTION WEIGHTS

Pen #	Fish Size	Production Weight (lbs)	Density (lbs/cuft)
1	L	16977	0.75
4	L	17369	0.77
5	L	9172	0.41
8	L	18792	0.84
2	S	16165	0.72
3	S	22355	0.99
6	S	10360	0.46
7	S	11157	0.50
Total		122347	
Average		15293	0.68

TABLE 7

BAY BULLS FOOD AND GROWTH SUMMARY

Pen #	Fish Size	Sort Weight (lbs)	Sort Density (lbs/cuft)	Production Weight (lbs)	Production Density (lbs/cuft)	Density Increase	Actual Growth	% Growth	Feed Days	Total Feed (lbs)	% Daily Growth	Food Conversion
2	L	21091	0.94	27081	1.20	0.26	5990	28.4	84	33320	0.34	5.56
4	L	15874	0.71	18984	0.84	0.13	3070	19.3	72	25488	0.27	8.30
6	L	17470	0.78	18482	0.82	0.04	1012	5.8	72	25422	0.08	25.10
7	L	18160	0.81	18109	0.80	-0.01	-51	-0.2	72	26853	0.00	-526.5
8	L	22939	1.02	21815	0.97	-0.05	-1124	-4.9	72	30239	-0.07	-26.90
10	L	21545	0.96	21505	0.96	0.00	-40	-0.2	72	29706	0.00	-742.65
14	L	28858	1.28	35680	1.59	0.31	6822	11.1	112	63593	0.10	9.32
16	L	24946	1.11	22187	0.99	-0.12	-2759	-11.1	80	37357	-0.14	-13.5
20	L	22464	1.00	24730	1.10	0.10	2266	10.1	72	17315	0.14	7.60
1	S	10224	0.45	14038	0.62	0.17	3814	37.3	84	37178	0.44	9.75
3	S	15642	0.70	20047	0.90	0.20	4405	28.2	84	32338	0.34	7.34
5	S	11973	0.53	15123	1.12	0.59	3150	26.3	72	34096	0.37	10.82
9	S	16620	0.74	15894	0.71	-0.03	-726	-4.4	60	15675	-0.07	-21.6
11	S	12665	0.56	11471	0.51	-0.05	-1194	-9.4	60	21395	-0.16	-17.92
12	S	15850	0.70	13469	0.60	-0.10	-2381	-15.0	84	6302	-0.18	-2.65
13	S	10652	0.47	15276	0.68	0.21	4624	43.4	84	43309	0.52	9.37
15	S	12062	0.54	18418	0.82	0.28	6356	52.7	84	34657	0.63	0.55
17	S	13738	0.61	16370	0.73	0.12	2632	19.2	112	24615	0.17	9.35
18	S	14650	0.65	16334	0.73	0.08	1684	11.5	56	12094	0.21	7.18
19	S	13877	0.62	14462	0.64	0.02	585	4.2	61	11269	0.07	19.26
TOTALS		341300		379475			38135			562221		
AVERAGES		17065	0.76	18974	0.87	0.11	1907	12.6	77	28111	0.15	-61.11

the only overall figures available (other than tagged fish data) and thus must be considered (Tables 4, 5, 6, and 7, Pages 25, 26, 27, and 28). The result of this variability has led, in a number of cases, to irrational figures particularly food conversion ratios (FCR) which refers to the number of pounds of food required to grow one pound of fish. One example of this was an FCR of -742.63 for pen 10 in Bay Bulls or 243.0 for pen 19 at Griquet. It could be argued that extraneous values such as these should be omitted because they don't fit the norm; however, this was not a scientific experiment in which an idea or theory is questioned, but is rather a presentation of facts on a farm by farm basis. Omitting any data for the simple reason of "not fitting" would be presenting a false account of what actually occurred. Suffice it to say that when examining Table 7, Page 28 it should be kept in mind that all data has been skewed by a disease outbreak. A number of pens from different farms were omitted (Tables 4 and 5, Pages 25 and 26) from summaries due to the fact that they suffered substantial escapemenmt through rips and tears, events which are important in the overall scheme but have no biological relevance.

Fish at all farm locations had capelin as their diet. Bay Bulls fish received some moist pellet feed mixed with antibiotics during the disease outbreak period (Sept 8-17), and pens 16 and 18 received moist pellet feed for 22 days (6725 lbs) and 31 days (3557 lbs) respectively in November as part of a capelin versus moist pellet feed experiment. Total capelin feed per farm site was: Griquet 412864 lbs; St. Lunaire 183960 lbs; Crouse 140355 lbs; and Bay Bulls 562221 lbs. Average % growth (weight) for each location was: Griquet 25.3%; St. Lunaire 32.4%; Crouse 24.0%, and Bay Bulls 12.6%. These figures converted to % daily growth (weight) were: Griquet 0.63%; St. Lunaire 1.20%; Crouse 0.51%, and Bay Bulls 0.15%. As can be observed in Tables 4 and 7, Pages 25 and 28, FCR values were extremely variable between pens in the same farm. Any pens with negative FCR values or high FCR values (above 10) should be viewed as suspect in terms of data accuracy. Extraneous figures indicate something out of the

ordinary occurred, such as disease mortality, escapement loss, fish moved to another pen with no record kept or a combination of such factors. Average FCR values for the respective farms were: Griquet 35.2 (high figure due primarily to pens 9, 19, 21, and 16); St. Lunaire 4.68; Crouse 5.94, and Bay Bulls -61.11 (skewed by disease outbreak).

The fish density figure is arrived at by dividing the sort weight of the fish by the maximum space available in an individual pen (22500 cu.ft., 637 cubic meters) which gives the pounds (kilograms) of fish present per cubic foot (cubic meter) of pen space i.e. the density. Average density for each farm site was: Griquet 0.65 lbs/ft³(10.41 kg/m³); St. Lunaire 0.69 lbs/ft³(11.05 kg/m³); Crouse 0.68 lbs/ft³(10.89 kg./m³), and Bay Bulls 0.76 lbs/ft³(12.17 kg/m³). Density is important in terms of growth as can be observed in Figures 6, 7, and 8 on Pages 31, 32, and 33 respectively. Each graph has individual pens plotted in terms of their % daily growth (weight) and density. The relationship revealed in all cases is that as density within a pen increases its % daily growth (weight) decreases. A graph was not plotted for Crouse as data was not available on an individual pen basis. Plots of individual pens with FCR and both density and % daily growth were performed for all locations as well, but due to the variability of FCR values of both Bay Bulls and Griquet the plots of neither location exhibited any consistent trend. The plots of St. Lunaire are presented as this location had the only consistent and "realistic" FCR values. Figure 10, Page 35 indicated that as FCR values decrease the corresponding % daily growth increases. Figure 9, Page 34 indicates that as FCR values increase the corresponding density increases as well, which implies that a lower stocking density will provide a better FCR.

3.7. Harvest and Production

Harvesting of fish began in the northern locations and ended with Bay Bulls, with comparable methods being employed

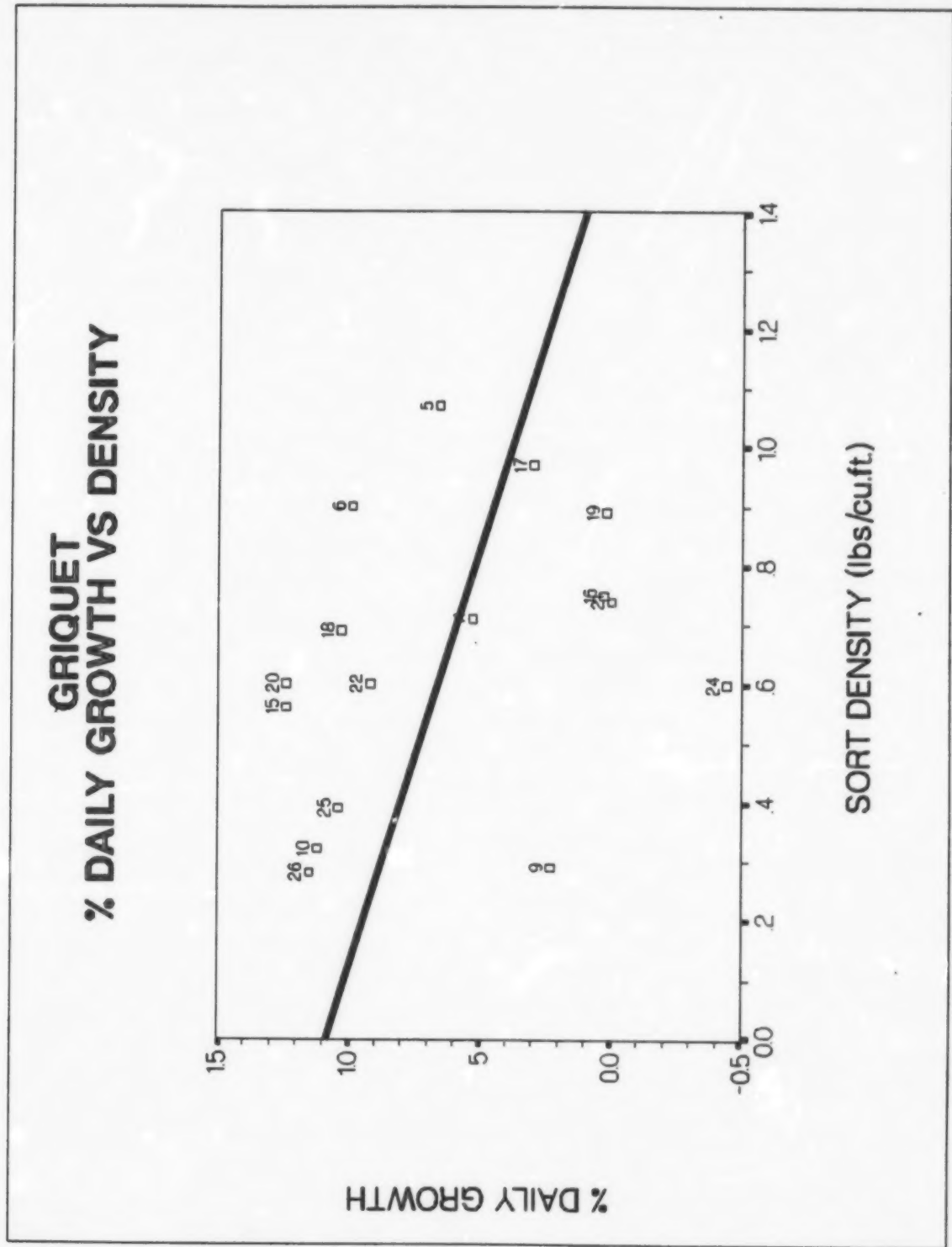


FIGURE 6

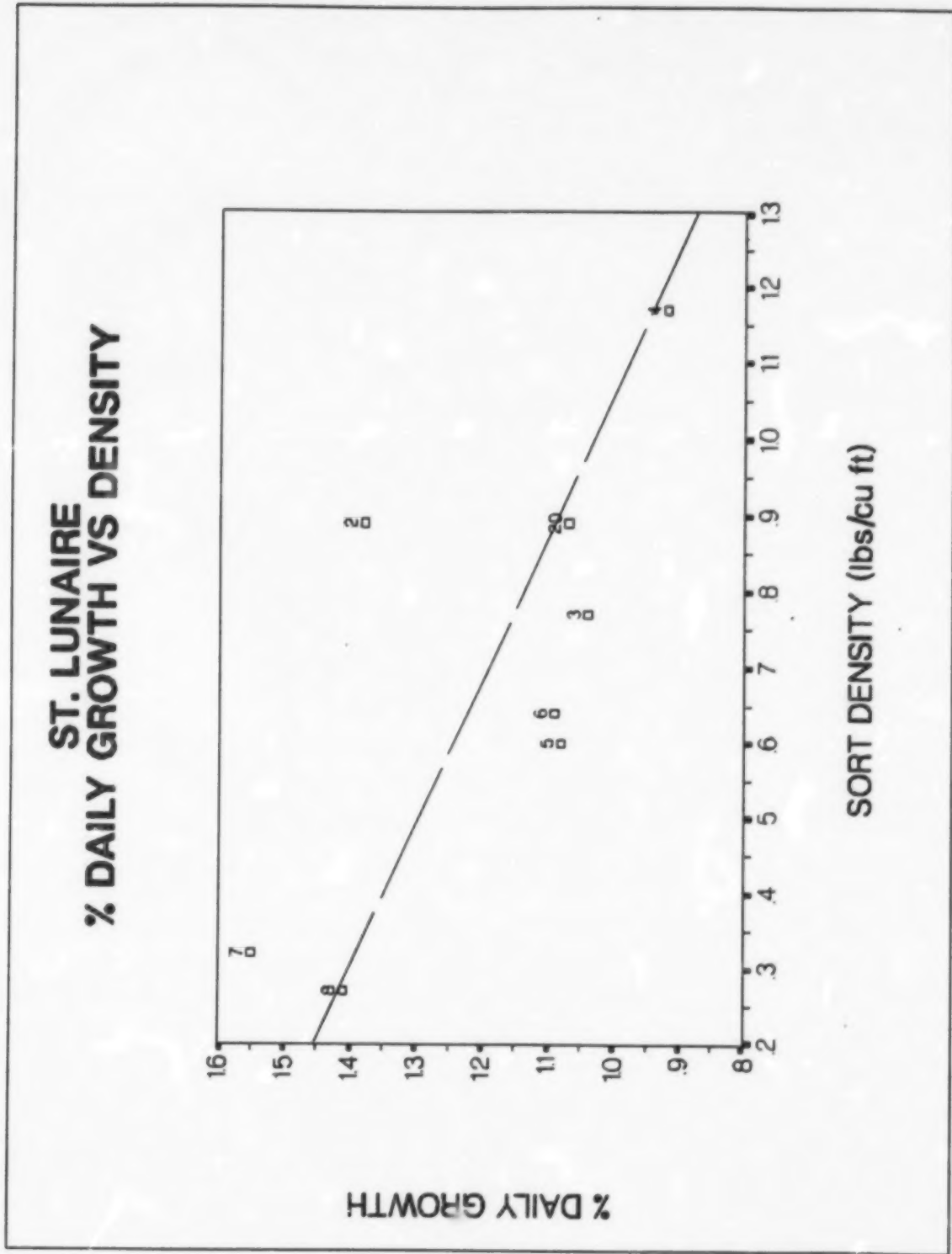


FIGURE 7

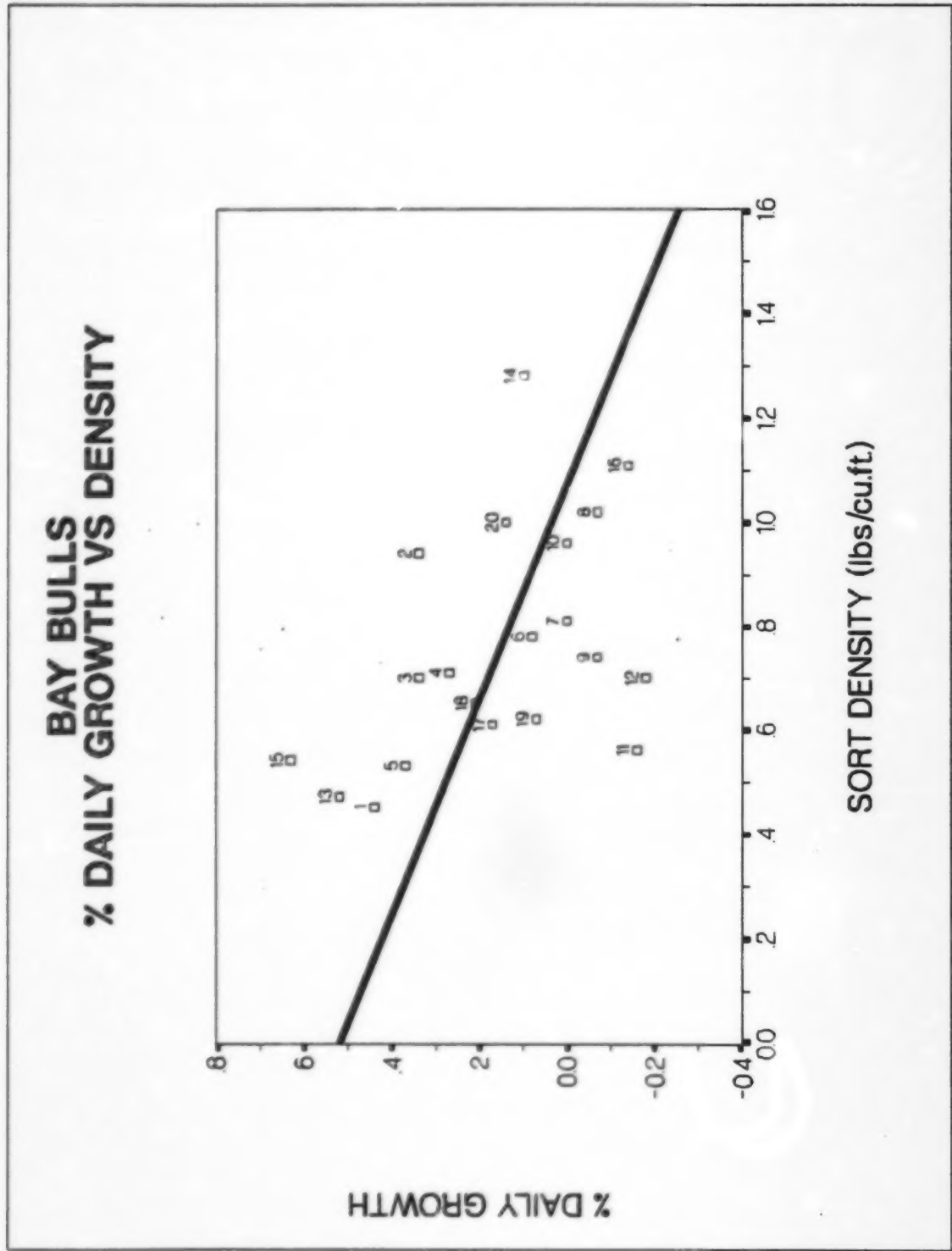


FIGURE 8

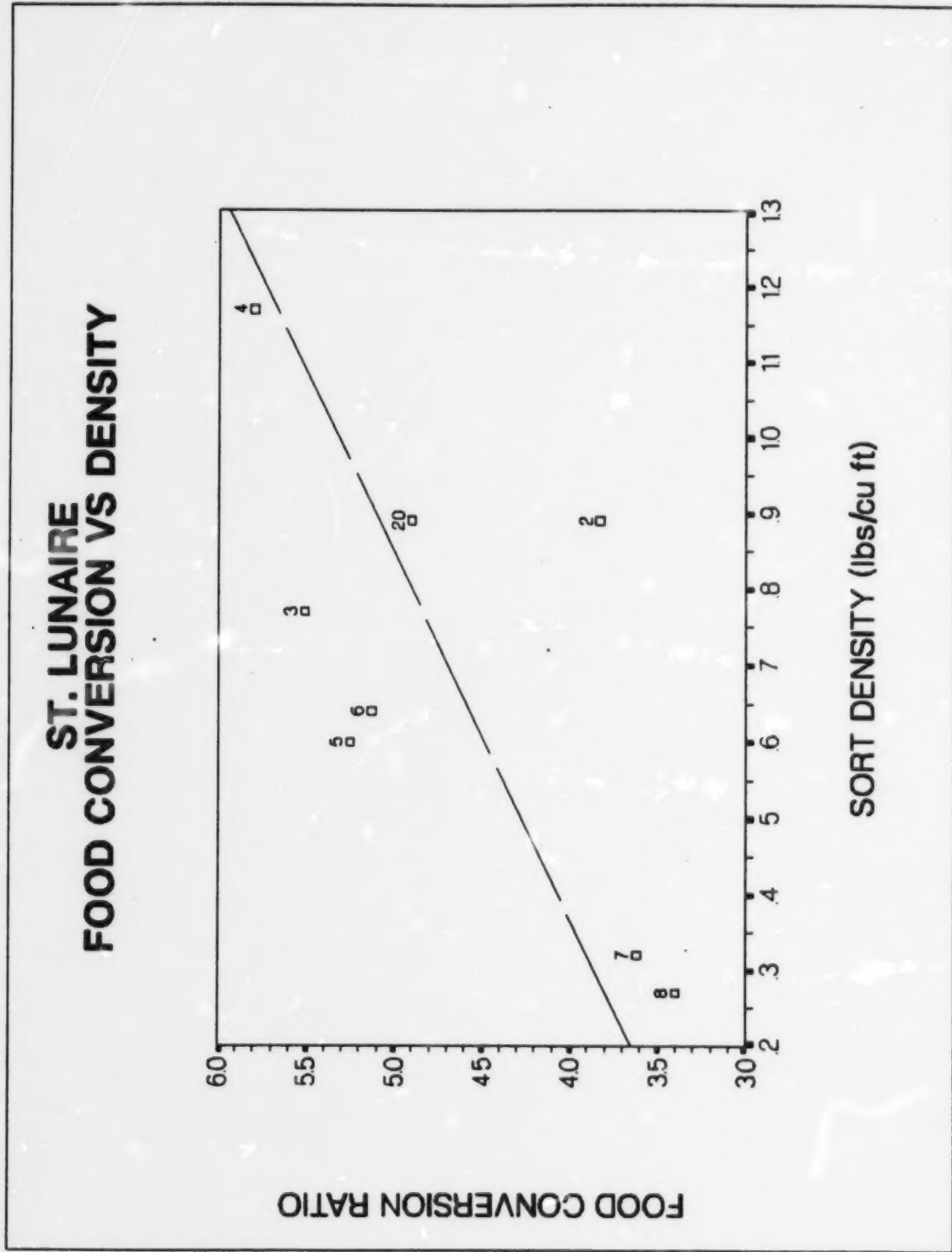


FIGURE 9

ST. LUNAIRE FOOD CONVERSION VS % DAILY GROWTH

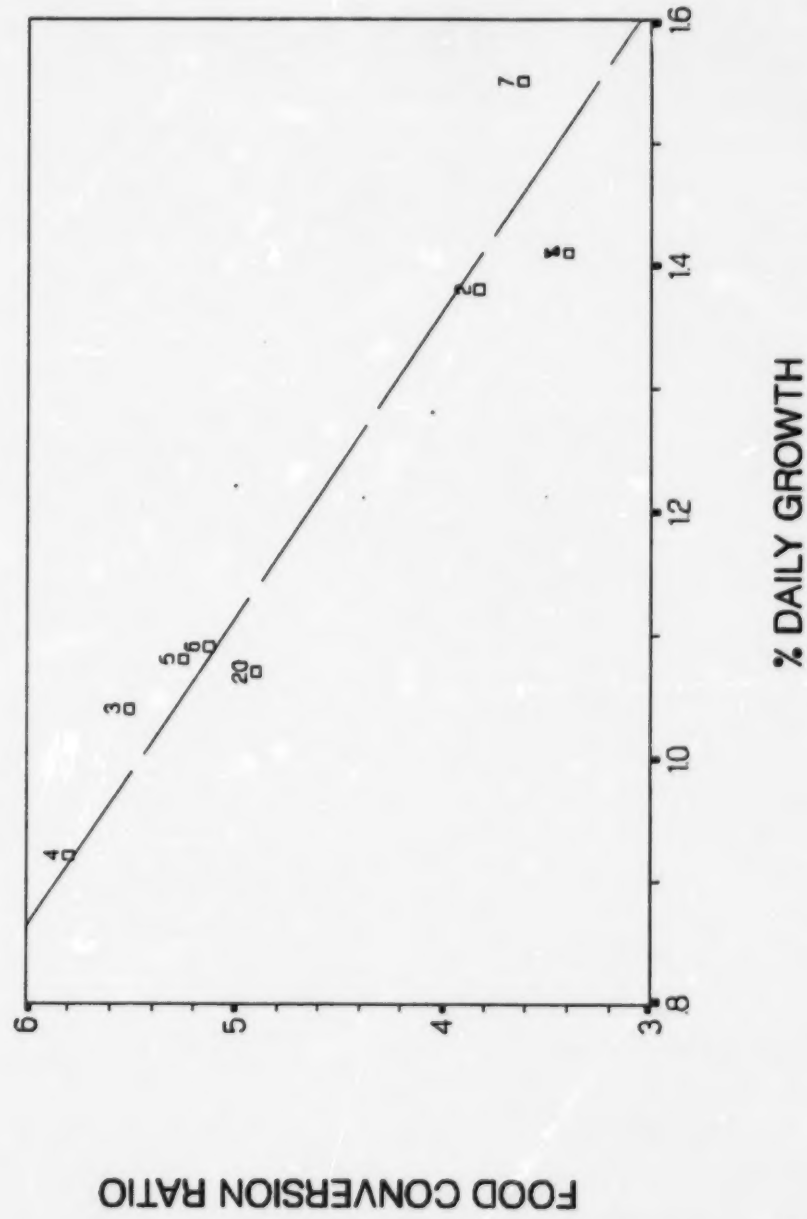


FIGURE 10

throughout. The harvest dates were as follows: St. Lunaire October 3rd to October 15th; Griquet October 17th to November 18th; Crouse November 7th to November 10th; and Bay Bulls December 7th to January 19th. The overlap between Griquet and Crouse was due to the fact that the harvest at Griquet was interrupted midstream to complete the smaller farm at Crouse. The onset of winter, coupled with poor road conditions at Crouse, was the chief concern. The extended time required for the Bay Bulls harvest was due to a break for the Christmas holiday season. All fish from St. Lunaire were processed at the Fishery Products International plant at St. Anthony, as were all fish from Griquet up to November 5th. From this point on, all fish harvested from northern sites were trucked by refrigerated tractor trailer to Witless Bay for processing. Fish harvested at Bay Bulls were processed at the Bay Bulls Sea Products Plant.

Total fish harvested from each location (Table 8, Page 37) was: Griquet 316824 lbs; St. Lunaire 184193 lbs; Crouse 112352 lbs, and Bay Bulls 380475 lbs. These figures combined to give 1003844 lbs harvested overall. A number of different products was produced from each location. Fresh fillets produced at each farm were: Griquet 108840 lbs; St. Lunaire 37543 lbs; Crouse 34651 lbs, and Bay Bulls 112585 lbs. Frozen block produced (mostly small fish for which there was no fresh market) was: Griquet 2960 lbs; St. Lunaire 2425 lbs; Crouse 380 lbs, and Bay Bulls 215 lbs. Minced product was produced from both Griquet and Crouse with 4158 lbs and 2970 lbs respectively.

4. DISCUSSION

4.1. Collection

The collection of starting stock is the most stressful phase in terms of fish health of the entire farming operation. Fish are prone to cuts and abrasions from crowding within the trap and collector boat holds, as well as from trap and dip net meshes. Many fish are subject to crushing weights in excess of 250 lbs

TABLE 8
PRODUCTION SUMMARY
ALL FARMS
(All Weights Are Pounds)

	St. Lunaire	Griquet	Crouse	Bay Bulls	Combined
Total Fish Bought	164880	350682	142798	478695	1137055
Sort Weight	147964	279987	98729	341911	868591
Harvest Total	184193	316824	112352	380475	1003844
Growth (Using Sort Weight)	36229	36837	23623	38564	135253
% Growth	24.5	13.2	23.9	11.3	15.6
Fillet Produced - Fresh Bone in Equivalent	33960	62340	5290	54029	155619
Fillet Yield - % Round Weight Fresh	22.7	19.7	4.3	14.2	15.5
Fillet Produced - Frozen Bone in Equivalent	3583	46500	29361	58556	13800
Fillet Yield - % Round Weight Frozen	2.40	14.68	24.00	15.39	13.75
Total Fillet Produced - Bone in Equivalent	37543	108840	34651	112585	293619
Total Fillet Yield - % Round Weight	25.1	34.4	28.3	29.6	29.2
Block Produced	2425	2960	380	215	5980
Block Yield - % Round Weight	1.62	0.93	0.31	0.06	0.6
Minced Produced	0	4158	2970	0	7128
Minced Yield - % Round Weight	0	1.31	2.43	0	0.71
Total Production	39968	115958	38001	112800	306727
Total Product Yield - % Round Weight	26.7	36.6	31.1	29.6	30.6

during dip net transfers. Fish undergo sharp pressure changes as a function of depth caused by quick trap hauls, which in turn causes distension, and often rupturing of the swimbladder. Fish are exposed to much higher light intensities than they are accustomed to. Substantial temperature differences are encountered between the trap, the collector boat hold and farm pens. If fish are glutted with capelin much regurgitation and defecation occurs in the collector boat hold, which clouds the water and results in increased ammonia and acid levels from digestive enzymes which also interferes with oxygen uptake over the gills. The noise and vibration from the collector boat motor and the boat motion itself causes fish stress. This is particularly evident with a small load where fish will crowd into the bow portion of the hold as far away from the motor as possible. Ellis (1981) states that stress can lead to reduction in fish immune response systems thus making them more susceptible to disease and infection. It would be impossible to eliminate stress altogether from a commercial farming process. However, this does not mean that it should be treated or considered only when problems arise.

The combined total transport mortality loss for all farms (Table 3, Page 23) was 19.8% (224945 lbs) with Crouse having the highest rate of 31.6%. It is difficult to speculate what resulted in this higher mortality at Crouse as it was not visited frequently. Possibilities include the unavailability of ice from time to time, long trips from the trap to farm site (in excess of two hours in some cases), and the fact that traps tended to be set at greater depths than other sites. More intensive on-site observations would be required to explain this phenomenon. Collection trips greater than 1.5 hours (unless conditions are ideal) are susceptible to increased mortality. A water exchange mechanism for the collector boats would contribute significantly to reducing transport mortalities. Painting the holds a dark colour may also reduce stress in terms of light intensity. If fishermen could be persuaded to haul traps slower than usual some of the pressure effects suffered normally may be minimized.

Holding cages situated alongside traps could allow fish during periods of capelin glut to void their systems, thus eliminating a large part of water quality problems associated with collection at this time.

4.2. Feeding

Immediately after capture, fish usually underwent a period of being "off their feed", particularly so if they were glutted with capelin. This period, presumably due to post-capture stress and unfamiliarity with their surroundings, could last anywhere from 5 to 10 days. After this short period, fish tended to feed voraciously on capelin provided at a theoretical amount of 6% of fish body weight every second day. Examination of farm feeding records however, indicate that this amount was extremely variable ranging from 2% to 13% on any given day. After approximately one month of feeding process fish appear to be "trained" in that when hungry they tend to become excited when boats/personnel arrive at the farm as if in anticipation of food. Fish also undergo a certain amount of stress during feeding in that competition is fierce and they tend to bump and scrape against each other and pen meshes. Limiting pen densities and sorting during collection can do much to alleviate this. Moist pellet feed was also introduced during an antibiotic treatment program and for a short-term moist pellet versus capelin feed study (both carried out at Bay Bulls). Initial trials with pellets were encouraging, with fish taking only two to three feedings to become accustomed, and were subsequently taking pellets quite readily; however feeding intensity never seemed to reach the levels observed using capelin. Observations indicated that a slowly sinking pellet may be most effective. Floating pellets tended to undergo a lot of breakage on the surface, and were also blown by the wind against pen meshes or corners and subsequently outside the farm before fish could get to them. SCUBA diving during pellet feeds revealed a "rain" of pellet fallout beneath cages. However, the amount lost due to this breakage is difficult to estimate.

Jobling (1985) states that due to the quick passage of pellet feed through the digestive system of cod much nutrient can pass through without being absorbed. To slow down this process it is suggested that large "chunks" of wild feed (capelin, herring, etc.) be mixed in with the pellets. These "chunks" require a longer breakdown period and thus slow down the passage of pellets through the digestive system allowing fish to obtain maximum nutritional benefit.

4.3. Growth

From tagged fish data (Table 1, Page 14) Griquet was found to have the highest % weight gain (66.5%) of all locations, followed by St. Lunaire at 46.71%, Crouse at 37.3%, and finally Bay Bulls at 19.08%. The low figure at Bay Bulls can be attributed to the disease outbreak which occurred mid August - early September. Infected fish were "off their feed" for an extended period of time and also received much less than their normal portions during the moist pellet - antibiotic treatment program. The high % weight gain from Griquet may be artificially induced as many fish collected appeared to have missed the capelin glut and were on the verge of nutritional deficiency. This was evident in reduced liver size, empty stomachs, and very dark gallbladders found upon internal examination of mortalities. These fish were then held for approximately one month in an unsuitable farm location, both in terms of dissolved oxygen and circulation. Fish at this site were observed breaching the surface regularly and staying consistently high in the water column, during which time the fish were feeding poorly, SCUBA divers released large amounts (500-800 lbs per pen) of uneaten capelin from various pen bottoms. After the farm was moved in early August, fish became much more active, stayed deeper in the water column, and began to feed voraciously. Fish were tagged at this time, and due to the fact that they may have had a feeding deficit to overcome subsequent growth, values encountered may have been abnormally high.

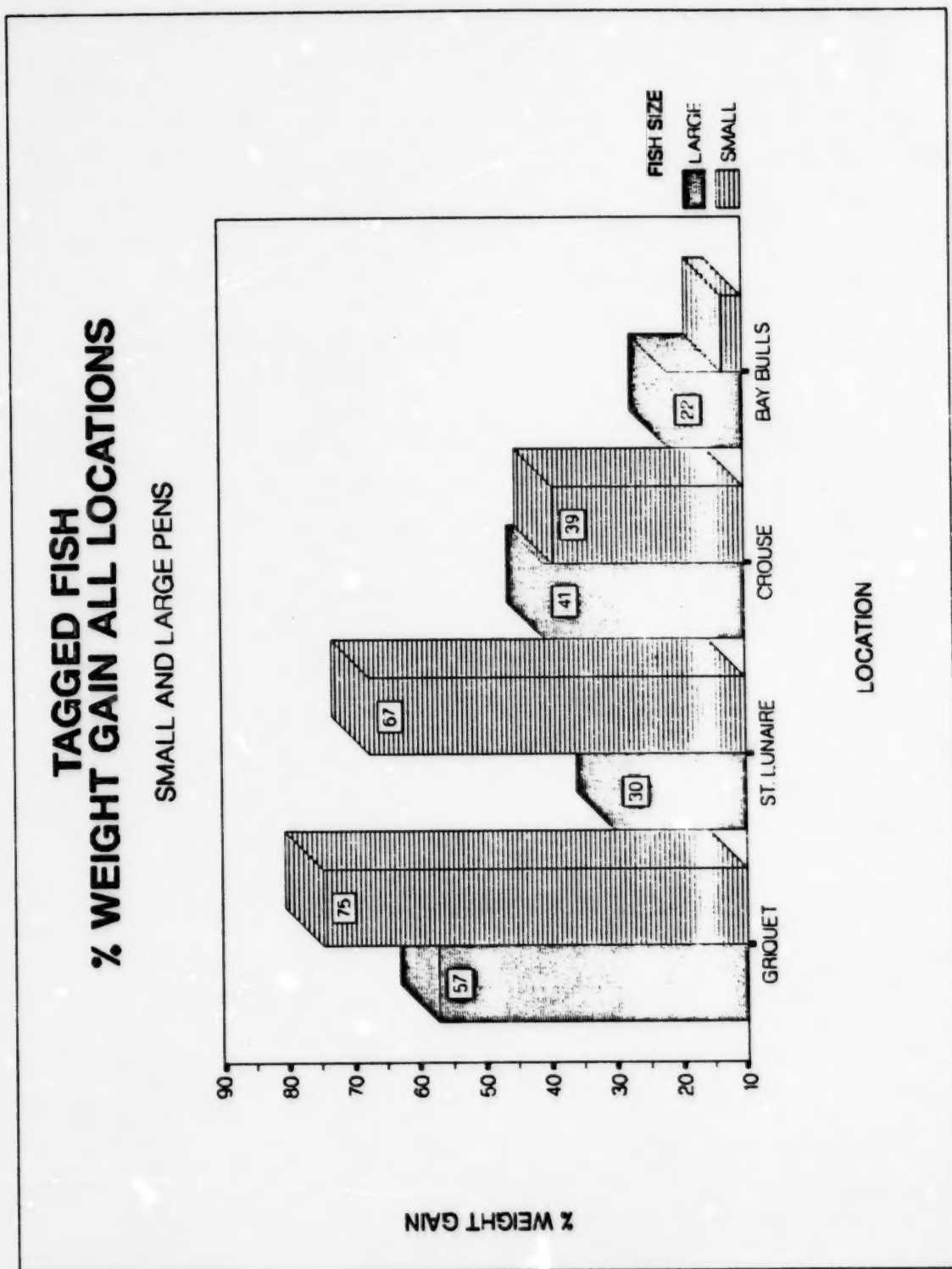


FIGURE 11

Kvenseth (1985) states that small fish have a higher growth rate generally than do large fish but the discrepancies between the two groups can be modified by temperature. With respect to % weight gain, this pattern held true for Griquet and St. Lunaire but not for Crouse or Bay Bulls (Figure 11, Page 41). Presumably at Bay Bulls small fish were much more susceptible to the effects of infection although it can be seen that large fish didn't fare particularly well either. Differences in % weight gain between large and small fish at Crouse are minimal, but nothing from data collected sheds any light upon this anomaly. In terms of % length gain small fish exhibited a higher gain than large fish at all locations (Figure 12, Page 43). Due to a number of extraneous variables such as different feed periods and different feed amounts, the only comparable value in terms of growth for the pellet versus capelin feeding experiment is the % increase per day. As can be observed from Table 9, Page 44 there were no appreciable differences in % length gain/day or % weight gain/day between capelin fed or pellet fed fish. Large fish, however, had a % weight gain two to three times larger than small fish. This is similar to the pattern exhibited by the rest of the tagged fish and again is due presumably to the greater effects of infection upon the smaller fish.

4.4. Production

Product quality from all farm locations was high. An independent contractor hired to assess the operation called it "the best product which I have had the pleasure to inspect". Farm fish were found to be broader in cross-section which resulted in a much stouter or "full" fillet than that obtained from wild fish. There were, however, a number of problems encountered in the overall process. Communication between the northern locations and St. John's was inadequate and often led to confusion over amounts and/or size of fish to be harvested on any given day. Poorly washed fish allowed mucous "slime" to remain on fish resulting in soft flesh. Problems with fish texture were encountered due to fish being packed improperly (not head to

TAGGED FISH % LENGTH GAIN ALL LOCATIONS

SMALL AND LARGE PENS

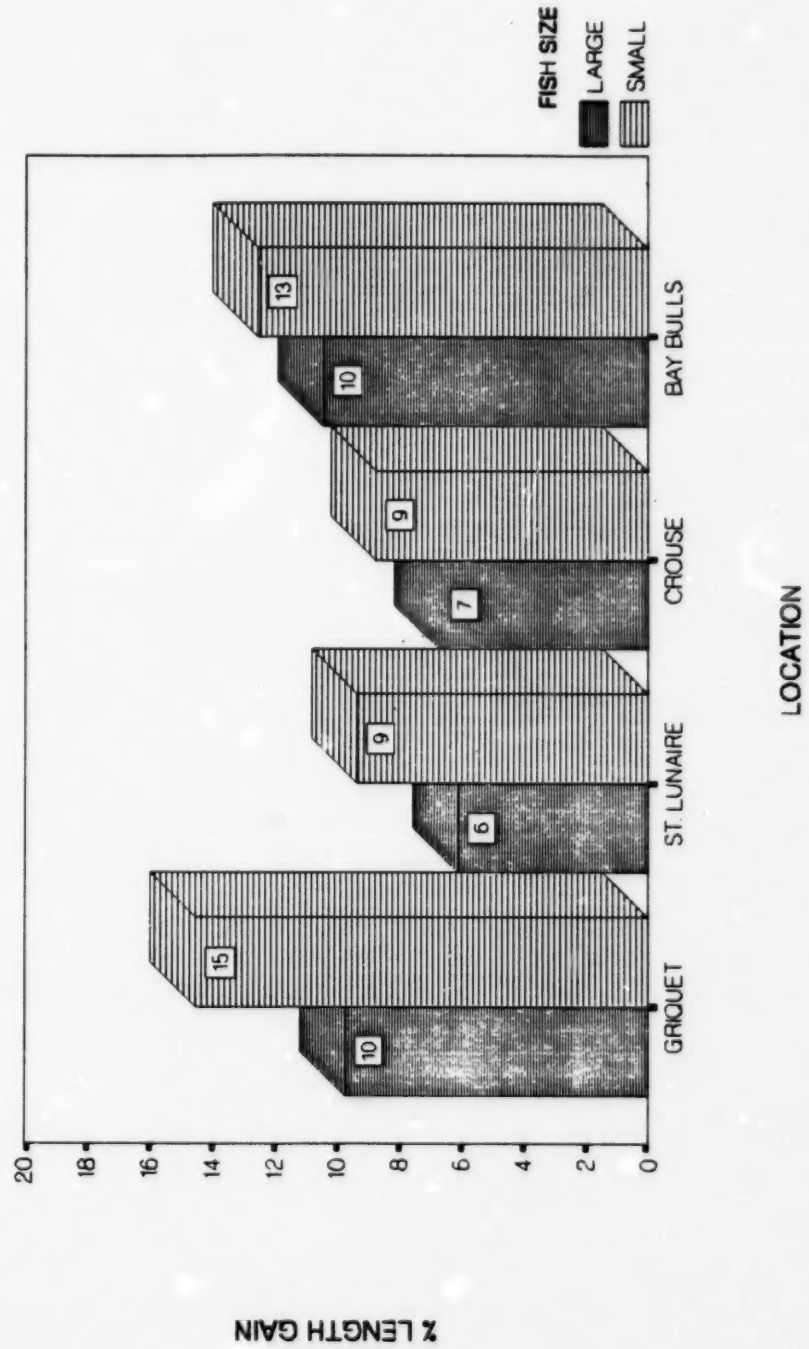


FIGURE 12

TABLE 9

BAY BULLS FEED EXPERIMENT

	Pen 14 Large Fish Capelin Diet	Pen 16 Large Fish Pellet Diet	Pen 17 Small Fish Capelin Diet	Pen 18 Small Fish Pellet Diet
Amount of Fish (lbs)	28858	24946	13738	14650
Density (lbs/cuft)	1.28	1.11	0.61	0.65
Amount of Feed (lbs)	17395	6725	7529	3557
Number of Feed Days	31	22	31	22
% Feed (of Fish Weight)	60.3	27.0	54.8	24.3
% Feed/Day (of Fish Weight)	1.9	1.2	1.8	1.1
Initial Length(cm)	56.2	59.9	49.4	51.9
Final Length (cm)	58.3	61.9	51.9	54.4
% Length Increase	3.7	3.3	5.1	4.6
% Length Increase/Day	0.12	0.15	0.16	0.21
Initial Weight (kg)	1.9	2.5	1.4	1.6
Final Weight (kg)	2.3	2.9	1.5	1.7
% Weight Increase	21.1	16.0	7.1	6.3
% Weight Increase/Day	0.68	0.73	0.23	0.29
Initial K-Factor	1.07	1.16	1.16	1.14
Final K-Factor	1.16	1.22	1.07	1.06
K-Factor Change	+0.09	+0.06	-0.09	-0.08

tail) and also from too much fish (greater than 70-100 lbs) placed in each pen. A number of fish were found to be gutted improperly which resulted in reduced yields and staining of the flesh. There were also times when fish shipped from northern locations could not be processed due to other plant commitments and this meant fish had to stand for an extra one or two days resulting usually in lower quality product. These problems are only minor in nature and can be easily rectified. They are also the exception not the rule and, for the most part, problems encountered during processing were logistical and didn't affect the quality of the final product.

It is recommended that a starvation period of at least two weeks to a month be undertaken for any fish to be harvested. This results in a clearing of the alimentary tract, a lowering of stored glycogen levels in the muscle (resulting in less intense rigor) and a decrease in liver size due to the fact that cod will utilize energy stores centered in the liver when feeding stops (Jobling, 1988). From tagged fish data (Table 1, Page 14) it can be seen that gonadal development was underway at all farm locations. In terms of % gonad weight, values ranged from 1.7% for males at Crouse to 5.5% for females at Griquet. According to Jobling (1982) weight gain decreases as the mature fish approaches spawning with a larger amount of food energy going into gonadal products. This implies that larger fish should be periodically sampled to determine the extent of gonadal development and harvested accordingly. This would reduce the amount of feed, time, and effort spent in the feeding of fish which are channeling much of the nutritional energy into gonadal development rather than growth. Blood sampling and subsequent examination of its hormonal components may provide an easier method of detecting the onset of gonadal development.

5. RECOMMENDATIONS

1. Have fisherman haul traps slowly as to minimize the stress fish undergo from quick pressure changes. This would

benefit the fishermen as well because more of their catch would be purchased by the farm.

2. Paint collector boat holds a dark colour (grey-green) to reduce stress from high light intensities.

3. Try to maintain collector boat holds at a temperature between that of the trap and the farm pen. Cooling hold water to 1 or 2°C with ice on a hot day when water temperature at the trap is 10°C and at the farm is 14°C only serves to increase stress on the fish. Collector boat skippers should determine temperatures at both the trap and farm and should try to adjust the hold temperatures accordingly to provide the least amount of variability.

4. Limit dip net loads to a maximum 150 lbs per dip. Dip net loads of up to 300 lbs were noted during the season resulting in net tears with subsequent fish loss, and crushing weights upon fish situated in the net bottom. Fish crushed by 300 lbs for 10-15 seconds are under severe, avoidable, stress.

5. The use of holding pens adjacent to traps into which fishermen could store live fish would be beneficial in a number of ways. Fishermen's time would be freed up much quicker as they wouldn't be involved in the actual collection process. Fish could be given time to clear their digestive tracts thus reducing transport stress from regurgitation. Collection trips could be better co-ordinated in that they would be assured of a full load with every trip.

6. Sort and weigh fish at the farm site during the collection phase. Weights taken at the trap are extremely variable due to water movement. Sorting at this phase would reduce cannibalism, allow small fish to feed better due to less competition, and remove subsequent stress due to a later sort. If this process is undertaken it should be done experimentally at first. This would be to discern if the added stress at this

stage is detrimental to fish survival, bearing in mind that some mortalities may not succumb for up to two weeks. Problems could also arise in terms of catch size, meaning that a "big run of fish" would result in lopsided pen densities between large and small fish which would then have to be transferred to other pens.

7. If possible, limit pen densities from 0.4 to 0.5 lbs/ft³ bearing in mind that pen densities will increase approximately 0.2 to 0.4 lbs/ft³ over the growing season. According to Figures 6, 7, 8, and 9, Pages 31, 32, 33, and 34, lower densities result in better food conversion ratios and higher % daily growth.

8. Develop a water exchange system for collector boats which would utilize a continuous flow of near-surface water to keep hold temperatures close to ambient water temperatures. Even with such a system in place ice may still be required under certain conditions to provide additional cooling and an oxygen system would probably still be needed due to high respiration rates of the highly stressed fish within the collector boat hold.

9. Avoid drawing up fish for any reason (i.e. sorting, tagging, pen shifting, etc.), when there is a substantial layer of fresh water on the surface due to heavy rains or runoff. Fish drawn up in this situation are being doubly stressed.

10. If fish are to be sorted during the growing season insure that they are starved at least 3-4 days before beginning the procedure. A number of times during the past season fish were observed regurgitating capelin and stomach fluids during sorting. This is added stress that can be avoided. After sorting, one regular feeding period should be skipped as well to allow fish to recover. Fish are usually "off their feed" for a short time after sorting anyway.

11. Introduce formulated feed as chief food source. The best method would be to incorporate large chunks of capelin into

the feed mixture to slow down food passage through the alimentary tract allowing fish to gain maximum nutritional benefit from pellets. Use of capelin is very labour intensive, and in the case of a large farm such as Griquet (30 pens) if all pens are full, use of capelin will strain both equipment and labor resources to the maximum. The use of formulated feed also allows the use of cheap protein sources such as offal and silage. Formulated feed pellets can be spread evenly over the entire pen (unlike capelin which is dumped in the center) giving all fish a better chance to feed. A vitamin pre-mix can be added periodically to formulated feed to improve fish health. Lastly, a mono diet such as capelin is not recommended for use over a long period as it can lead to nutritional deficiencies.

12. Cod should be observed very closely during the peak temperature periods of the season for signs of infection (lumps, swellings, lesions, aggravated behavior such as rubbing against mesh etc.) and immediately acted upon by incorporating antibiotic into the feed.

13. Temperature should be taken into consideration when calculating feed amounts. According to Jobling (1988) appetite increases with increasing temperature, reaches a peak and then declines as temperatures continue to increase. He also states that appetite in small (30-45 cm) fish peaks at a higher temperature than appetite in large (70+ cm) fish. During the previous growing season feed weights were calculated using only a percentage of estimated weight of fish contained in the pens. This practice probably means that fish are being fed at less than optimum levels.

14. During collection, pens receiving fish should be cleared every day by SCUBA divers. Fish could be placed into a net bag and winched to the surface by a collector boat for possible sale to the local plant. This would keep the area under the pens clean, reduce strain upon pen twine (large amount of fish in pen bottoms have been observed to stretch twine to

depths of 30-35 feet, changing the entire pen configuration), recoup some of the financial losses from purchasing unusable fish, allow much more accurate records to be kept in terms of mortalities and pen densities, and remove any diseased or bacterially infected fish from the site thus reducing the risk of disease outbreak.

15. Net inspections for rips, tears and holes should be carried out on a weekly basis. Farms at Griquet and St. Lunaire lost an estimated 19900 lbs of fish due to escapement (Table 3, Page 23) which could have been avoided by proper weekly net inspections.

16. Discontinue use of nets which contain the funnel structure at the bottom, or tie up funnels completely. These nets are very labour intensive in terms of removing mortalities during SCUBA dives. They also give the net another 5-6 ft in depth making them more susceptible (when stretched) to contact with the bottom. Unlike zippered pens, when large amounts of dead fish are distributed fairly evenly over the bottom, funneled nets concentrate all the weight into a small area which pulls the net into a "cone" shape greatly decreasing the upper pen circumference. Most importantly, fish were observed many times to be trapped within the funnels trying frantically to free themselves. This stress can be avoided.

17. Proper hygiene and cleanliness practices should be stressed at all locations both on the farm itself and in onshore facilities. Onshore facilities should be hosed down daily and cleaned thoroughly on at least a bi-weekly basis with proper cleaning agents. Farm pens should be cleared of all debris on a daily basis, taking into consideration that any piece of decaying matter is a possible source of bacterial and viral contamination. Anything recovered should be brought inshore and disposed of properly.

18. It would probably be wise to move the farm at Bay Bulls

to a new location as three years of fish excrement, dumped diseased fish during last season's outbreak, spilled feed, and fallout from pellet feed have taken their toll on the bottom environment. Bottom ions are high at the present location as can be observed from the white bottom layer covering the entire area. This location should be left for 1-2 years to enable it to renew itself. It should also be noted that the Bay Bulls site is not desirable at the best of times due to fish plant effluent, boat traffic (often dumping oil and refuse), offal dumping, and fresh water runoff from the surrounding community.

19. More emphasis should be placed on direct local studies of perspective farm sites. Water current conditions, water quality, and amount of water exchange should be investigated. Pollution prone areas with effluent from industry and communities should be avoided. Bottom studies need to be conducted to avoid oozy and clay-like (oxygen poor) areas in favour of rocky or gravelly substrate. An area well protected and free from wind may not be the best site as this is necessary to carry away spilled feed etc.. Lastly, a minimum depth of 60-70 feet should be required due to the fact that last season mortalities in net bottoms stretched pen twines to depths of 35 feet where they were resting on the bottom in danger of tearing. Pen twines did not conform to their original shape and thus fish were very close to previously dumped decaying mortalities. Because fish contain natural bacteria in skin and muscles which are released upon decaying, this is not a desirable situation.

20. Proper laboratory facilities (dissecting equipment, microscopes, jars, vials, preservatives, digital scales, slides, sink, workbench, etc.) should be made available at the farm site. This would allow biological staff to conduct more meaningful research and investigate in more detail any problems which may arise. Co-operation financially and in terms of manpower for such a facility could possibly be obtained from Memorial University (Ocean Science centre, Logy Bay) the Marine Institute, and Fisheries and Oceans. Much more detailed research

is required in many areas of the cod farming process, and proper onsite facilities may encourage outside research interests which would be beneficial to all parties involved.

REFERENCES

- Conroy, D. A. and R. L. Herman (1970). Textbook of fish diseases. T. F. H. Publications N. J. 07303 U.S.A.
- Ellis, A. E. (1981) Stress and modulation of defence mechanisms in fish. In Pickering, A. 1981. Stress and Fish. Academic Press. London.
- Fisher, R. F. (1988) Assessments and Observations of a Cod Farming Operation in Newfoundland.
- Jobling, M. (1982) Food and growth relationships of the cod *Gadus morhua* L., with special reference to Balsfjorden, north Norway. J. Fish. Biol. 21 357-371.
- Jobling, M. (1985) Growth in Fish Energetics - New Perspectives P. 213-230 eds. P. Tytler and P. Calow Pub. Croom Helm, London.
- Jobling, M. (1988) A review of the physiological and nutritional energetics of cod *Gadus morhua* L., with particular reference to growth under farmed conditions. Aquaculture 70: 1-19.
- Kvenseth, G. ed. (1985) Guide to Cod Rearing. Norwegian Office of Fisheries Ocean Research Inst., Dept. Aquaculture (Trans. IRB, St. John's NFLD).
- Roberts, R. J. and C. J. Sheperd. Handbook of Trout and Salmon Diseases (2nd ed.) Fishing News Books Ltd. Surrey, England.